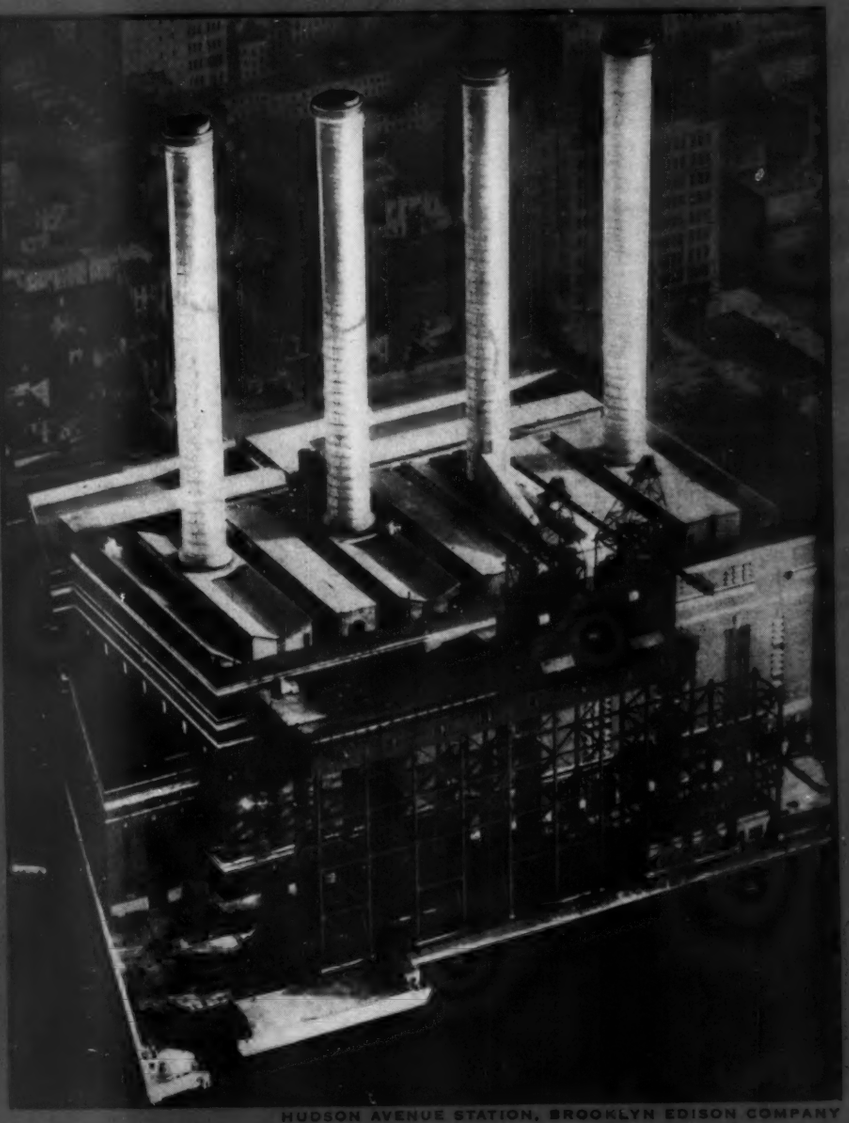
COMBUSTION

Vol. 1, No. 8 | FEBRUARY 1930 | 25 c. a co

Engineering Library
FEB 5 1930



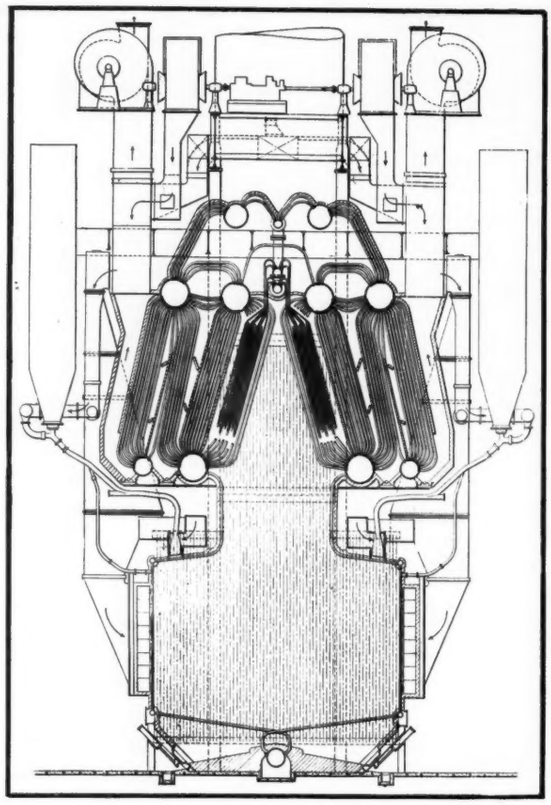
HUDSON AVENUE STATION, BROOKLYN EDISON COMPANY

From Towering Firs to Kilowatts
By WILLIAM A. STRUTHERS

Steam Pressure Control for Stations Operating on a Two Pressure System
By JAMES L. KIMBALL

Other Articles in This Issue by

A. F. DARLAND • W. L. DeBAUFRE • DAVID BROWNLIE • B. J. CROSS



Cross section of one of three steam generating units installed at the East River Station of the New York Edison Company.

1,250,000 pounds of *Steam* per hour from a *Single Boiler Unit* . . . . . .

THIS unit is one of three, each originally designed to produce 800,000 lb. of steam per hour. Within two months from the date of placing the first unit on the line, steam had been produced at the rate of 900,000 lb. per hour and recently this capacity has been increased to a rate of 1,250,000 lb. per hour—for a short period.

The boilers, water-cooled furnaces, air preheaters, pulverized fuel firing and Raymond grinding equipment were all designed, made and installed by Combustion Engineering Corporation.

Combustion Engineering Corporation

200 Madison Avenue **New York, N, Y.**

A Subsidiary of International Combustion Engineering Corporation

COMBUSTION

Vol. 1 FEBRUARY 1930 No. 8

CONTENTS

Feature Editorial—

In 1930 Become an Engineer 23
by Harvey N. Davis

Feature Articles—

From Towering Firs to Kilowatts 25
by William A. Struthers

Steam Pressure Control for Stations Operating on a Two Pressure System 30
by James L. Kimball

Engineering Units 34
by Wm. L. De Baufre

New Developments in British Industrial Steam Station Practice 39
by David Brownlie

Airplane Carrier Lexington Helps Tacoma Meet Power Emergency 44
by A. F. Darland

How to Calculate the Air Required for Combustion and the Air Actually Supplied 46
by B. J. Cross

Description of the Hams Hall Power Station, Birmingham, England 48

Editorials—Modern Steam Plants Have a High Reliability Factor—
Fred R. Low Retires 24

News—Pertinent Items of Men and Affairs 51

New Catalogs and Bulletins—A Review of Current Trade Publications 53

Review of New Technical Books— 54

New Equipment—

Feed Water Treatment 55
Improved Gas Analyzers 55
Dust Collecting Fan 55

Patents—Recently Granted in United States and Great Britain 56

Advertisers' Index 63

CHARLES MCDONOUGH, *Business Manager* — CARL STRIPE, *Editor* — H. STUART ACHESON, *General Representative*

Published Monthly by

IN-CE-CO PUBLISHING CORPORATION

GEORGE E. LEARNARD, *President* GEORGE H. HANSEL, *Secretary* W. I. BRANIGAN, *Treasurer*

A SUBSIDIARY OF INTERNATIONAL COMBUSTION ENGINEERING CORPORATION

NEW YORK—International Combustion Building, 200 Madison Avenue

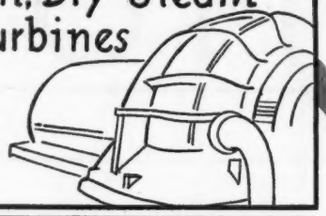
LONDON—Africa House, Kingsway, W.C. 2

SUBSCRIPTIONS, including postage, United States and Canada, $2.00 a year, Great Britain 8 shillings. Other countries, $3.00. Single copies: United States and Canada, 25 cents. Advertising rates furnished upon application.

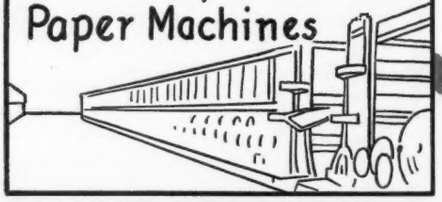
Copyright 1930 by In-Ce-Co Publishing Corporation, New York. Printed in U. S. A. Publication office, 200 Madison Avenue, New York.

NUMBER OF COPIES PRINTED THIS ISSUE, 11,031

Clean, Dry Steam to Turbines



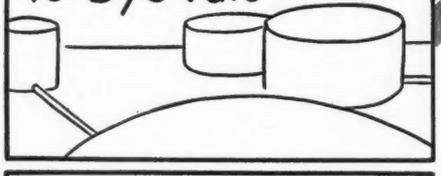
Clean, Dry Steam to Paper Machines



Clean, Dry Steam to Tar Burners

Clean, Dry Air to Air Tools

Clean, Dry Steam to Dye Vats

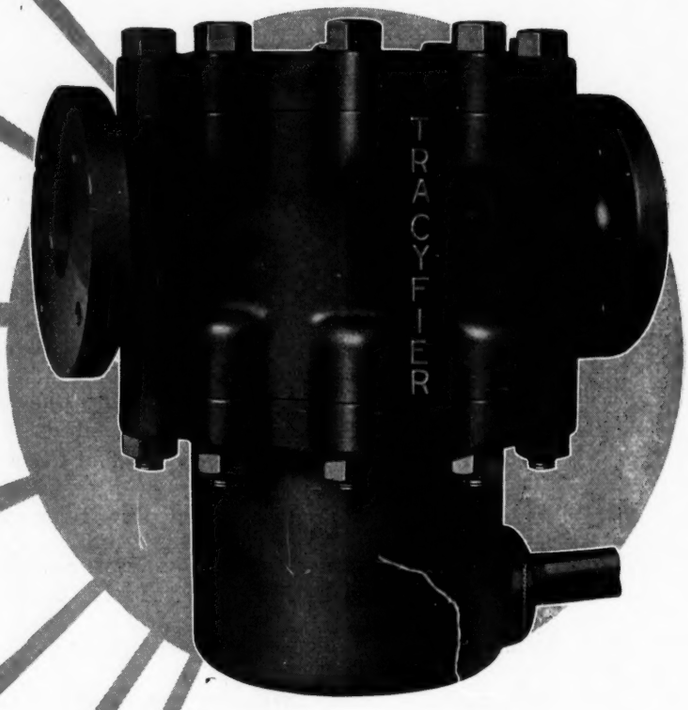


Clean, Dry Steam to Laundry Machines

Clean, Dry Steam to Filters

The Pipe Line Tracyfier HAS MANY USES

IN MANY INDUSTRIES



WHENEVER *absolutely* clean, dry steam, air, or gas, is wanted, the PIPE LINE TRACYFIER will deliver it. The same principles are used as in the well known TRACYFIER, now in boilers aggregating over 3,000,000 H.P.

Delivery of STANDARD SPECIFICATION STEAM guaranteed. (Do not confuse this precision-built instrument with an ordinary separator). Can be furnished to handle any quantity or pressure of steam, air, gas or vapor.

Ask For New Bulletin Number 1047.

BLAW-KNOX COMPANY

TRACYFIER DEPT.

2039 Farmers Bank Bldg., Pittsburgh, Pa.

BLAW-KNOX

COMBUSTION

Vol. 1 February 1930 No. 8

In 1930 Become an Engineer

HARVEY N. DAVIS

IN the November "AMERICAN," Emil Ludwig remarks: "The century, above all else, determines what the exact nature of a man's activity shall be. In 1200 the man who wished to distinguish himself became a crusader, in 1500 a bandit, in 1800 an iconoclast, and in 1930 he will become an engineer." This tribute to our profession, from the author of "Bismarck" and "Napoleon" is significant. It marks a notable change in professional life and professional training.

Twenty years ago, when there was need of a wise and sagacious man for some position of large responsibility in business or public life, the choice usually fell on a lawyer. Therefore, when a young man of high ability, but without predetermined ideas as to a career, desired a higher education, he naturally turned to a liberal arts college and followed it by a course in law, whether he expected to practice law or not. Nowadays those same young men of high ability are more and more turning to the engineering schools for a training that will stand them in good stead in a wide variety of activities often seemingly unrelated to engineering itself. They are founding their mental lives on the spirit of science, rather than on the spirit of precedents. They are learning to attack problems on their own merits instead of inquiring what grandfather did under similar, or apparently similar, circumstances. They are preparing themselves for the great adventure of forging out utterly new solutions for many of the problems of business, of social service, and of government, solutions based on a clear and unprejudiced assembling and understanding of the facts.

This is why so many young men, about to graduate from high school, are saying to themselves "When in doubt, select an engineering course." And this is why we in the engineering schools are striving, as never before, to give our students well rounded educations, educations that will furnish a background of English and history and economics and philosophy, as well as a thorough foundation of science, mathematics and mechanics, unspecialized educations, educations that will prepare for life as a whole as well as for the technique of a profession.

"In 1930 the young man who wishes to distinguish himself will become an engineer."

Harvey N. Davis

President,
Stevens Institute of Technology.

EDITORIAL

Modern Steam Plants Have a High Reliability Factor

AT EAST RIVER STATION, New York, one of the boiler units after being operated for eighteen consecutive months, was taken out of service, inspected and put back on the line without a replacement or repair.

The new boiler plant of a large industrial company was designed for two years' continuous operation for each unit, without shutdown.

A number of plants report twelve months' continuous operation of individual boiler units and many turbo-generators have record runs of several years without the casing being removed.

These are outstanding examples of dependable service but they are indicative of the constantly increasing reliability of modern steam stations.

Recall for a moment the average industrial steam plant of twenty years ago. Then, plant operation was a battle against time. First, could the equipment hold out until the regular weekly overhauling, and second, could the repair gang get things patched up over the weekend, in time to pick up the load on Monday morning?

The plant engineer of 1910 was a worthy contemporary of the early automobile owner who worked throughout the week dismantling and re-assembling his car so that he might enjoy his regular hundred mile trek on Sunday.

Engineering standards have been raised.

Weekly rebuilding and roadside repairs are no longer associated with motor cars.

The shovel, oil can and monkey wrench are no longer symbolic of steam power.

Many factors have contributed to the increased reliability of boiler plant operation.

Small, inefficient industrial steam plants have been abandoned, or rebuilt and re-equipped in order to meet the competition of the modern public utility plant which has served as both a threat and an example.

Better initial designs of equipment and plants have been developed and better materials and construction methods are now available.

Maintenance crews, organized separately from the regular operating force, keep all equipment in first class running order through continuous inspection and repairs.

The chemist and the engineer have joined hands in converting feed water treatment from a sad state of engineering quackery to a subject of intelligent scientific research.

The human element has been replaced, where practicable, by mechanical provision for automatic control of fuel, feed water and air. Supervision is of a higher order—by better equipped men, better schooled in fundamentals and capable of assuming greater responsibilities.

This improvement in steam plant reliability is much more than the casual result of advancement in steam engineering. Greater reliability has been demanded by economic necessity, for, as units increased in size, they represented larger initial investments and higher fixed charges. Hence, the cost of outage became increasingly greater.

With all-metal water-cooled furnaces, pulverized fuel firing, proper feed water and intelligent operation—the reliability of the modern steam generating unit is remarkable.

And, the same factors which have brought greater reliability, have brought improved operating efficiency as well.

Fred R. Low Retires

A HALF century of conspicuous service in power plant engineering and technical journalism has earned for Fred R. Low, retiring editor of *Power*, the respect and esteem of the engineering fraternity.

As an engineer, Fred Low is recognized as an authority on power plant subjects. He has been one of the most active members of the American Society of Mechanical Engineers since 1886 and after serving as member or chairman of the Power Code Committee, Boiler Code Committee, Fuels Division and Executive Committee, his identification with the Society reached its climax in 1924 when he was made president.

As an editor, he served for forty-two years and contributed much toward raising the standards of engineering journalism. His untiring efforts exerted a tremendous educational influence on the entire power plant field.

As a man, his character, intelligence and unselfish devotion to his chosen work, were an inspiration to all who were privileged to know him.

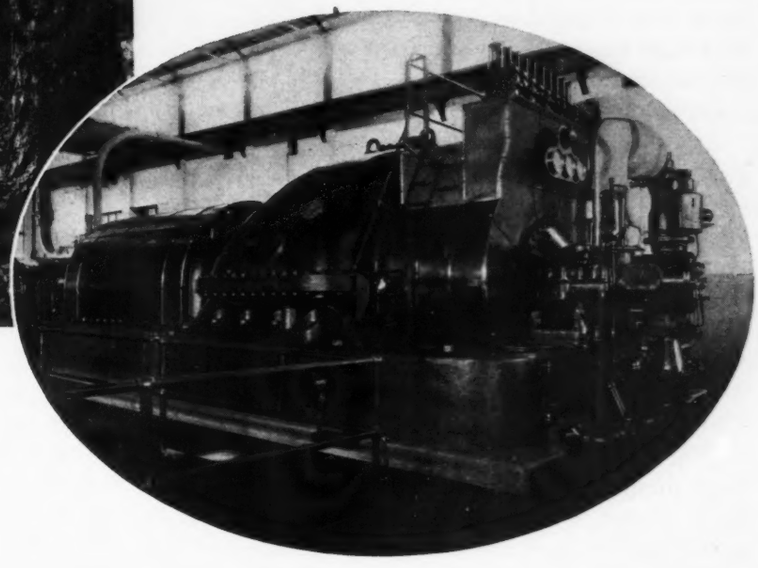
In Mr. Low's retirement from active work COMBUSTION adds this modest message of recognition and felicitation to the many tributes and good wishes of his host of friends in every branch of engineering and industry.

From Towering Firs *to* Kilowatts

By William A. Struthers

Portland Electric Power Company, Portland, Ore.

The story of Hog Fuel which plays an important part in the generation of steam and power throughout the Northwest.



Steam is supplied to the 20,000 kw. generator shown on the right by boilers fired with Hog Fuel, a by-product of the lumbering industry in the Northwest. This generator is installed in the plant of the Portland Electric Power Company, Portland, Oregon

ONE might think of the water which drives great hydro generators as coming from the realms of towering pines and firs, or we may think of the woods as being the starting point of coal deposits which in ages to come will be converted into electrical energy. But there is another path from the woods to the power station which involves large logging camps, huge log rafts on river or ocean, and great sawmills which convert the logs to lumber for the world's markets. These sawmills send about 30 per cent of the total wood as sawdust and other waste material to nearby power stations to be burned under modern boilers. This source of power is peculiar to the Pacific Northwest, but is of major importance in that section.

There are hundreds of sawmills operating in the states of Oregon and Washington from which more lumber is exported than from any other part of the United States. The amount of waste wood from these plants is astonishing. It is estimated that about 2.5 million tons per year are wasted by sawmills cutting Douglas Fir, while about 1.7 million tons are wasted by the factories working up this lumber. Some of this waste wood is turned to useful work in small boilers at the mill or factory, while a larger portion is delivered to large power stations as fuel for modern boilers. Many other uses are being found for the wood waste, but there is still a large amount being thrown away or burned for disposal.

It is a pleasant and very interesting experience to visit the great woods of pine, fir and cedar and follow the path of the logs as they proceed towards the lumber markets of the world.

In the great logging camps the trees are generally cleared of branches and the top is cut off before the tree is felled to prevent damage to the trunk. The long log is then raised by a system of cables which are fastened to the tops of trees and pulled by a donkey engine over the tops of the down timber and underbrush. It is deposited in a pile or loaded direct on trams or cars to be moved to the sawmill or to the river. If the logs are to be transported by water they are usually made up into long rafts held together by cables. The rafts are then towed by a tug to the mill pond. In some cases this requires a sojourn down to the Pacific Ocean and along the

coast to a harbor, or up another stream to the particular sawmill.

It is interesting to watch the "head saw" tearing into a log six to eight feet in diameter, and maybe sixty or more feet in length. Some saws cut a swath three-eights of an inch wide as they slab the log and at a ferocious speed. A man would have to run to keep abreast of the log as it runs past the saw. Some mills use band saws altogether. These make a narrow cut and hence less wood is wasted but they cut slower. These first saws usually slab the log only, or cut it into quarters in order that it can be handled by the smaller "recut saws."

The recut saws, which cut the lumber to its final size, usually cut a narrower band. They usually are of the band saw type. Part of the rough lumber is loaded into ships for the world's markets, while other portions go to be kiln dried and are then planed and cut into edgings, sidings, or various other commercial shapes before leaving the sawmill.

The sawdust and shavings from all these saws and cutters together with edgings, broken boards, trimmings from boards or slabs, and in some cases the slabs themselves, are considered a waste product and must be disposed of. Millions of tons, especially of slab wood, have been used for filling large depressions. At times a layer of wood was alternated with a layer of gravel. Many such fills are found in the West, and it is surprising how long such a fill holds its elevation.

Other mills disposed of this waste by burning it in large incinerators. In this manner millions of tons were wasted. Some mills still consider it more economical to do it this way. This is because of the high cost of transporting it from their particular mill

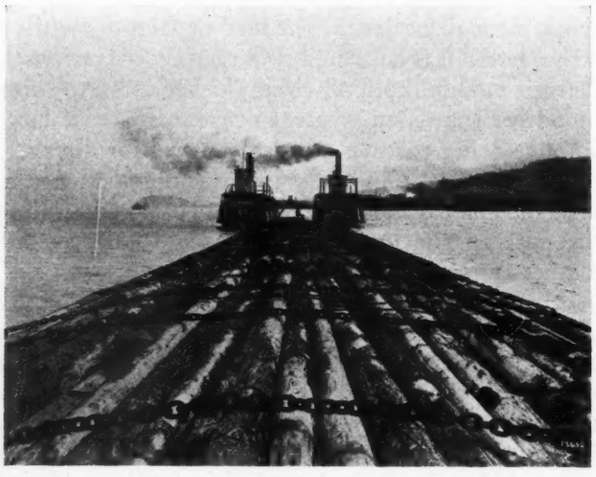


Fig. 1—An Ocean-Going Log Raft in the Columbia River

to a market, or the cost of converting it to power for their own use.

When the waste material is to be burned under boilers, the large pieces, such as broken boards, scraps of slabs, etc., are reduced to scraps six or eight inches long by passing them through a machine called a "hogger." In this the boards are knocked into many pieces by teeth fastened to shafts which rotate at a very high speed. The products of these machines are mixed with the sawdust and shavings

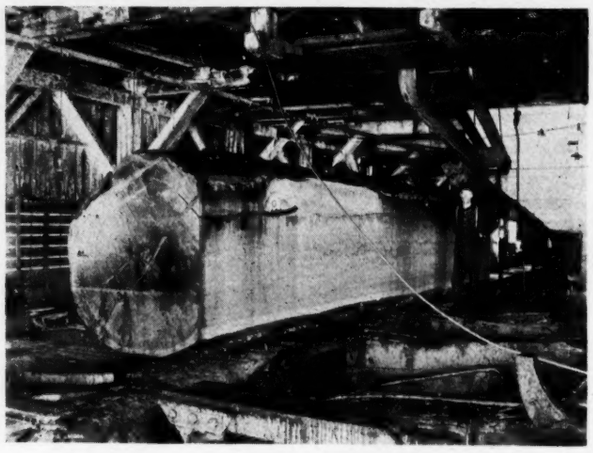


Fig. 2—Fir Log Being Slabbed by a Band Saw

on the conveyors and the resulting mixture is termed "hog fuel."

If the sawmill is near the power station the hog fuel may be transported by a conveyor consisting of an endless steel chain with cross bars of wood which drags the material through the conveyor chute, lined with steel plates. This is the type of conveyor usually used around the boiler plant. Other conveyors, such as belt or pneumatic conveyors, have been used and still are to a small extent. However, the chain conveyor, although crude in appearance, seems to remain the cheapest and most reliable conveyor for hog fuel.

Other sawmills are forced to transport their hog fuel by train or by barges to the consuming boiler plants. The barges used each hold about 200 units of 200 cu. ft. per unit. They are loaded and unloaded by clam shell buckets or by a specially constructed fork which is the most recent development.

Most steam plants of the West are operated partly or totally for peak load or stand-by power. Therefore the storage of fuel is of utmost importance. Hog fuel is stored outside in huge piles, usually dragged on to the pile by steel prong rakes pulled by cables. It is reclaimed by dragging it to the conveyors. A fairly large pile contains about 41,200 units of two hundred cubic feet each. Each unit contains about 4,300 lb. of fuel, so the pile contains about 88,500 tons of hog fuel.

There is some loss of fuel value from seasonal storage of this type. This is due to slow oxidation and loss of volatile due to heat of decomposition. During extreme wet weather this heat may be sufficient for spontaneous combustion. The remedy consists of retarding the burning by smothering with

other hog fuel and then to convey the smoking mass to the boilers and let it burn over the grates.

The fuel contains varying percentages of moisture, depending upon the amount of kiln dried shavings it contains. Very few consignments run less than 35 per cent, while we have had daily averages of fuel to the boiler plant from the storage pile which ran over 63 per cent moisture. A yearly average of a typical pile ran 47 per cent moisture.

In the past the abundance of fuel has made it cheaper to burn more fuel than to attempt to conserve the 20 per cent or more of fuel, which is possible, by removing this moisture. The exit gases from most boilers contain enough waste heat to dry their incoming fuel. As the demand for fuel increases undoubtedly methods will be developed to utilize this heat economically for the removal of moisture.

The B.t.u. value of Douglas Fir, which constitutes the largest part of such fuel supplies, is about 8,800 B.t.u. per lb. of dried fuel, or about 20,000,000 B.t.u per unit of hog fuel. This is burned under modern boilers with an over-all boiler efficiency of about 60 per cent, delivering about 12,000,000 B.t.u. to the steam per unit of hog fuel. Let us compare this with a typical fuel oil which runs about 6,216,000 B.t.u. per barrel of 42 gal. and can be burned with an over-all boiler efficiency of about 80 per cent. A barrel of oil would deliver 5,772,800 B.t.u. to the steam. Thus, one unit of hog fuel is equivalent to 2.1 barrels of oil. The hog fuel can be delivered to

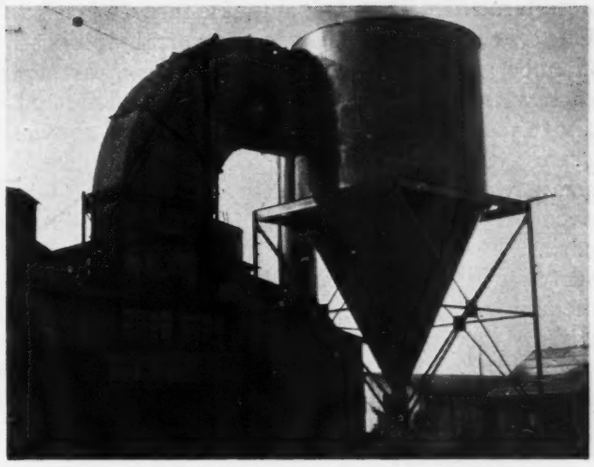


Fig. 3—Typical Cinder Cone used for removing small particles of ash and charcoal from stack gases

our boilers at a cost of about $1.25 per unit. This would require that oil be procurable at about sixty cents per barrel in order to be comparable, instead of its more common price of about $1.15 per barrel. Of course, there are some operating and maintenance costs which favor oil. But this difference in cost explains the general use of hog fuel where the material is available.

One boiler recently added to the plant of the Portland Electric Power Co., in Poreland, Ore., may prove of interest. This boiler, which is shown in Fig. 5, operates at 415 lb. pressure and is rated at 1667 boiler hp. Since the installation was desired partly for standby service, it was desirable that it be run at

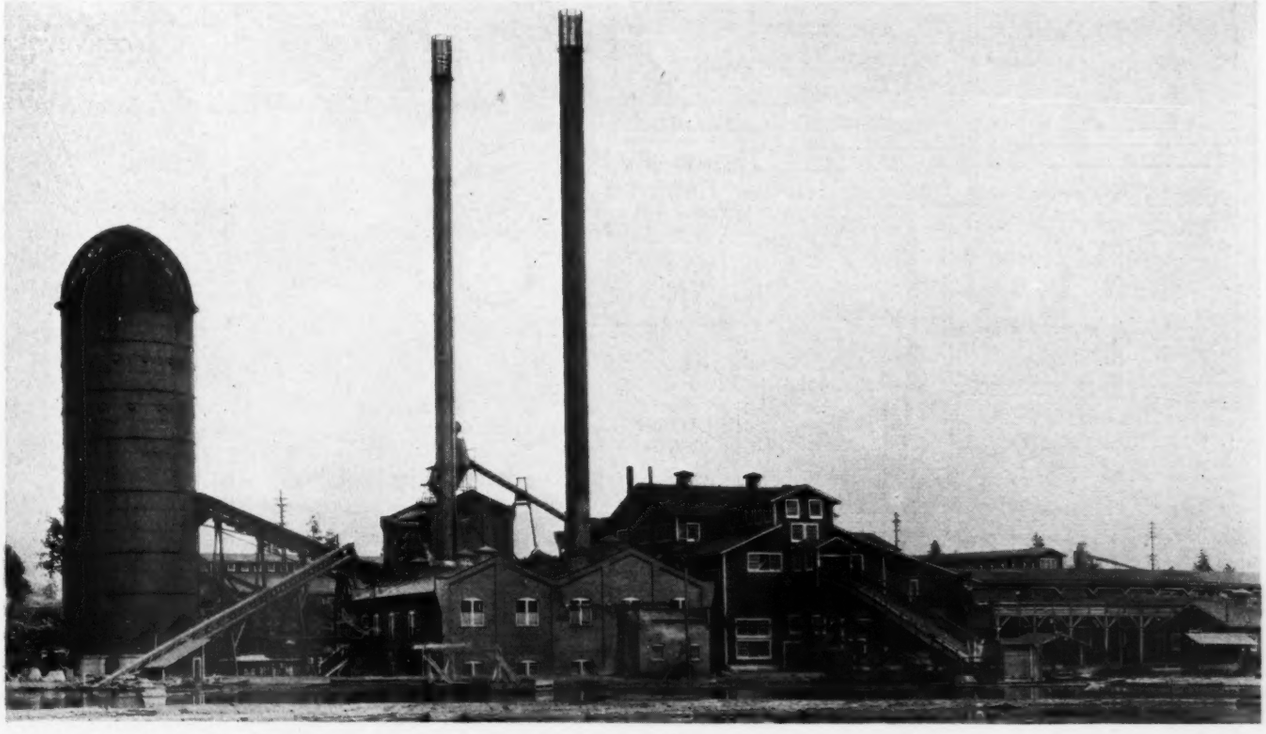


Fig. 4—Typical Saw Mill. Note the boiler plant in the center which furnishes power for the mill by burning Hog Fuel, and the large incinerator at the left where the excess, thousands of tons of wood waste, is being burned merely for disposal

a high rating. Therefore a double furnace was built. On two opposite sides of a central combustion chamber were built four Dutch oven compartments, each with 64 sq. ft. of grate area. Air preheated to above 500 deg. fahr. is forced in below and above the grates, while the fuel is fed continuously through a small swinging door above the center of each Dutch oven. The fuel stands in a cone and burns almost entirely on the surface. This setting has been very successful. Boiler ratings above 500 per cent can be secured and this boiler alone can furnish steam for a turbine carrying above 22000 kw.

Some little grate trouble has been encountered, but water-cooled grates seem to be solving the difficulties. Figs. 6 and 7 show a comparison between plain cast iron grates and water-cooled grates. After three months service, 80 per cent of the cast iron grate bars were gone, whereas water-cooled grates in a similar compartment with similar service showed practically no deterioration. The heat from the grates is not lost but is utilized at the first step in heating the feed water make-up.

Hog fuel contains only about 0.4 per cent ash and this is extremely fine and light. Some passes up with the smoke and the removal of that which falls below the grate is a simple matter. One laborer per shift with a wheel-barrow can remove the ash for the plant.

Hog fuel plants are not free from the smoke evil, but their problem is slightly different. Commonly the smoke particles consist of a mixture of small particles of ash and particles of clean bright charcoal. Practically all of the ash passes a screen of fifty mesh to the inch and the charcoal ranges in size from three-eighths inch in diameter down, depending upon the gas velocities. The mixture of ash and charcoal is termed "cinders" in this locality.

The most satisfactory method of removing this material from the gases, from a smoke nuisance standpoint, is to wash it out with water as is shown in the diagram, Fig. 5. But with this method the disposal of water and cinders is a problem and the charcoal is wasted. The most common means of cinder elimination is with a cyclone dust remover. In many cases the cinders are returned to the Dutch oven to be burned.

However, the material, if screened, is such clear, clean charcoal that it would seem to have some higher priced utility than as a boiler fuel. There is

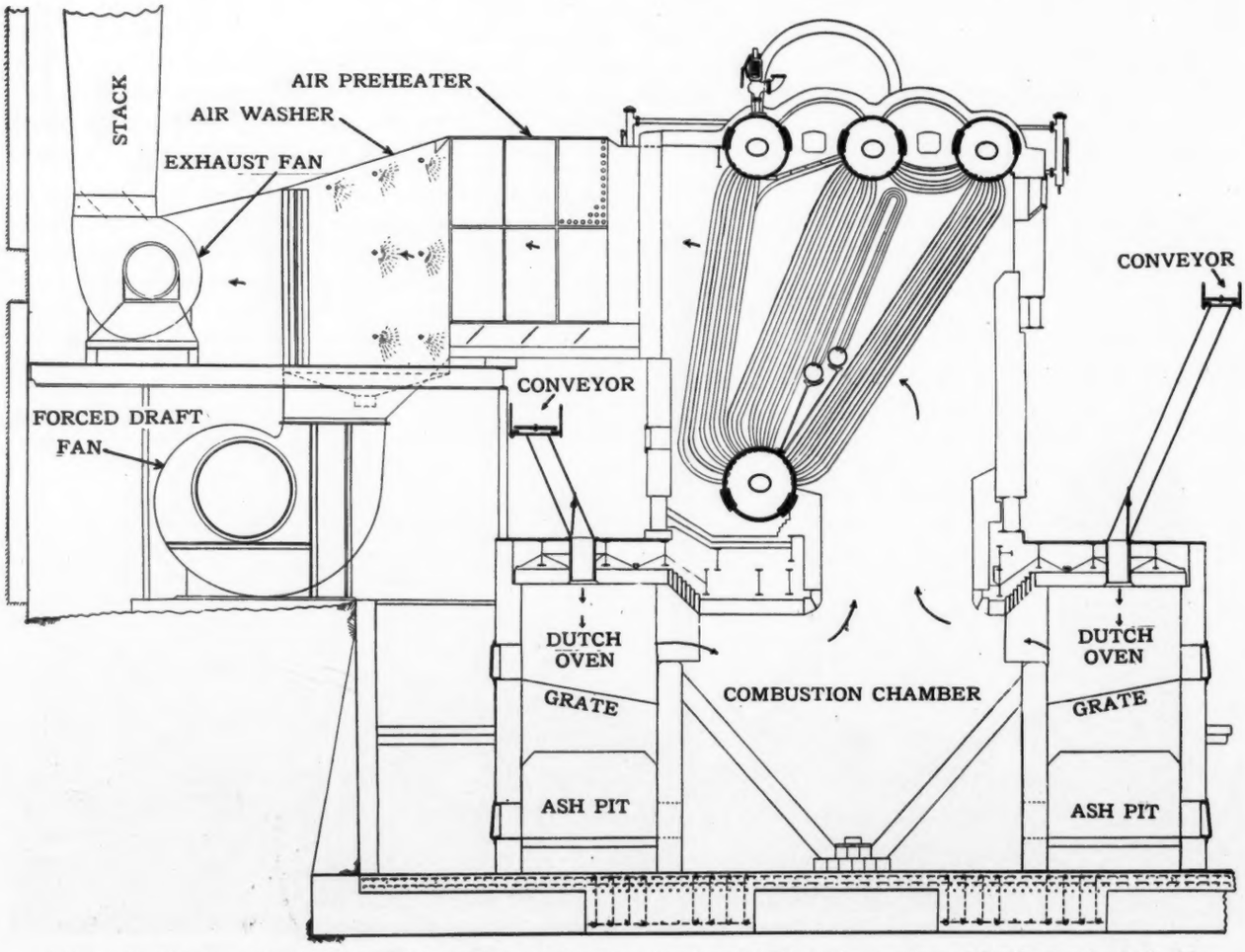


Fig. 5—Section through a 1667 hp. boiler designed for burning Hog Fuel. This boiler is operated by the Portland Electric Power Company, at Portland, Oregon

room for research work here in applying this charcoal product to some need in other industries. One plant produces from 5 to 20 tons of it per day. It has been suggested as a layer to prevent oxidation in kettles of lead, etc., in metallurgical plants. It surely would prove an excellent fuel for the production of carbon dioxide for beverages or carbon dioxide ice. It may have many other applications. The proximate analysis of a typical sample taken from a cyclone dust separator or cinder cone is as follows:

Proximate Analysis of Material from Cinder Cone

Moisture	1.1 per cent
Ash	16.4 per cent
Volatile Combustible Matter	3.0 per cent
Fixed Carbon	79.6 per cent
Sulphur	None
B.t.u. per lb. as received	12,320

Material Screened Through 48 Mesh Screen

	Larger Than 48 Mesh	*Through 48 Mesh*
Per cent of total Material	61.00 per cent	39.00 per cent
Per cent of Ash	1.8 per cent	39.20 per cent
B.t.u. per lb.	13,880	8,760

Hog fuel is also being put to other uses. Many attempts have been made to utilize it as a raw material for wood distillation. There are two factors that mitigate against the success of such a process on Western soft woods: First, the low yield of turpentine and wood tars; and second, the low demand for such products. Research work is being done on the conversion of wood tars to motor fuels and other useful products. Such work may bring forth a commercial process in the future.

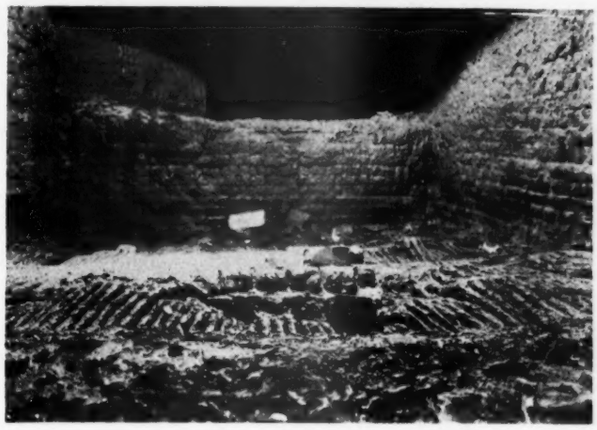


Fig. 6—Cast iron grates after three months' service

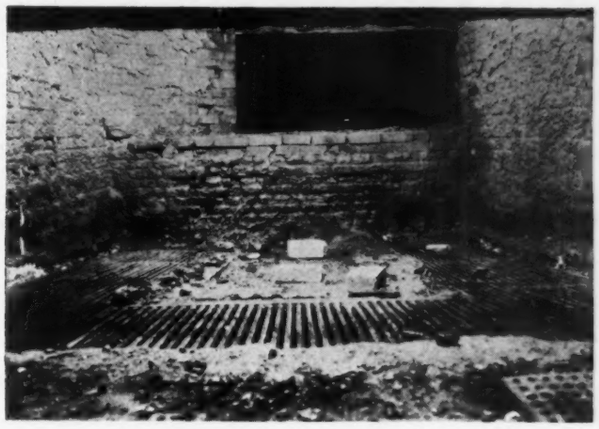


Fig. 7—Water cooled grates after three months' service

Waste wood products are being converted to sound and heat insulation boards. The pieces are fiberized by saturating them with high pressure steam and then exploding it by suddenly releasing it to atmospheric pressure. The fibers are then molded into boards by pressure and heat. Although this industry is new, its future seems assured.

Domestic hog fuel burners have been taking a considerable amount of waste wood for house heating the last few years. Such furnaces, with large hoppers for feed, are almost automatic in operation. They give a very uniform heat at about one half the cost of coal and have proved very successful.

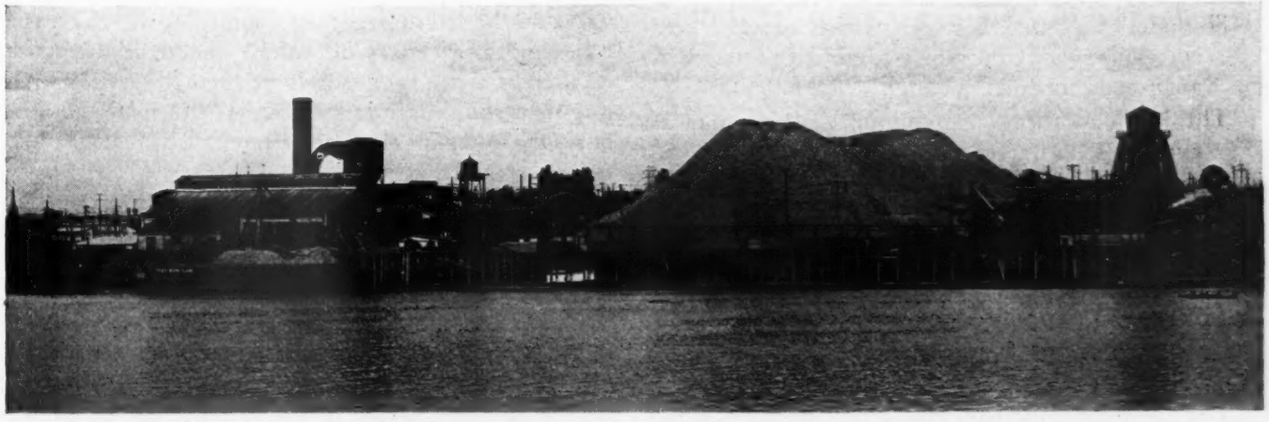


Fig. 8—The Largest Sawdust Pile in the World. On the right is a large saw mill and on the left is a power generating station

Steam Pressure Control *for* Stations Operating *on a* Two Pressure System

By James L. Kimball,
Mechanical Engineer, Ruggles-Klingemann Mfg. Co., Salem, Mass.

The effective utilization of high pressure steam gives rise to numerous questions affecting the selection and arrangement of pressure control valves, especially during the period when it is necessary to operate with two pressures before the station is completely changed over to the higher pressure cycle. This article presents a practical and informative discussion of this problem.

THE applications of regulating valves to pressure control in steam plants are so numerous and varied that it is impossible to cover the entire subject in a short article of this kind. It will, therefore, be necessary to confine this discussion to the problem of the extended central generating stations operating under two pressure conditions.

It is obviously advantageous that boilers for the new high pressures be operated at sufficiently high ratings, not only to supply steam of high pressure and high total temperature to the new generating units, but to supply the older types of generating units with as much steam as is required, or as is possible to generate for peak load requirements.

This means that the steam evaporated by these high pressure boilers in excess of that required for high pressure generators must be reduced in both pressure and temperature to meet the requirements of the older generating units.

The problem, at first thought, would appear to be a comparatively simple one, for certainly reliable regulating equipment for this purpose must be available, but no regulating equipment can be expected to give satisfactory service unless selected with a clear understanding of all the operating conditions which it must serve.

A few of the more important questions to be decided are the following:

First: The minimum and maximum weight of steam to be passed.

Second: The limits between which reduced pressure must be maintained—commonly referred to as pressure operating range.

Third: Fluctuations in volume demand due to average load fluctuations.

Fourth: The excess weight of steam which could be discharged to the atmosphere in case of failure of reducing pressure valve, without producing a disastrous effect on the water level of the boilers.

Fifth: The most satisfactory type of reducing valve for the purpose.

The answer to question No. 1 is required in order to determine the size of valve, and whether a single reducing pressure valve will meet the requirements, or whether the load range is such as to require two or more reducing valves, in multiple, operating in progressive order. It is well understood that a comparatively large size reducing valve, working close to its seat on light loads, is subject to over-correction of pressure and consequent hunting action. Therefore, if the load range is comparatively wide, it is desirable to use two or more valves in multiple.

From the answer to question No. 2 it is possible to determine how many valves can be used in multiple, operating progressively, before the total pressure operating range will be too wide between the minimum and maximum demand for the operating conditions.

The information called for in question No. 3 must also be taken into account, otherwise the pressure operating range—sometimes called compensating effect—may not be sufficient to prevent overtravel due to time lag.

Now we come to question No. 4, which brings up the most important requirement of a reducing pressure valve, and one which, if not taken into consideration, may seriously interfere with the continuity of service, due either to burnt boilers or wrecked turbines.

The question of safety of equipment is, of course, of prime importance, and next to this comes the question of uninterrupted service. No one for a moment would consider placing a single pop safety valve on the steam header of a sufficient size to do the relieving for a battery of boilers. Then, what excuse is there for using a single reducing valve which might, through failure to perform its proper function, not only interrupt the service but cause great damage to property.

The logical conclusions would, therefore, appear to center on the use of several independent control valves in which the failure of a single unit would not be disastrous either to equipment or to service.

The factor of safety from multiple valves, operating in progressive order, is twofold. First, it affords greater protection to the boilers, and second, it avoids dumping steam to the atmosphere at a time when the boilers are operating at high ratings and

are generating no more steam than required to maintain the station load.

Assuming that instead of a single reducing valve we connect the high and low pressure headers together with three separate steam connections of a much smaller size, and install in each of these three connections a reducing pressure valve. Now supposing that the reduced pressure is 200 lb. and that No. 1 valve was adjusted to close at 196 lb., No. 2 valve at 198 lb., and No. 3 valve at 200 lb. And, further assuming that the load is such that No. 3 valve is wide open, and No. 1 valve closed, with No. 2 valve doing the regulating. If something should happen to No. 2 valve which caused it to open wide, then No. 3 valve would close a corresponding amount. Supposing that No. 2 valve, instead of opening should close, then No. 1 valve would open and simply shift places with No. 2 valve. The same would be true if No. 2 and No. 3 valves were open and No. 1 valve regulating. If No. 1 valve opened wide, then No. 2 valve would close a like amount. The worst that could happen would be that this valve would close with the other two valves open and consequently drop some of the load.

Assuming that No. 1 and No. 2 valves were closed, and No. 3 valve regulating, the worst that could happen would be to have this valve open wide, as in this case, No. 1 and No. 2 valves being closed, the excess steam would be released to the atmosphere. On the other hand, if this valve should accidentally close, No. 2 valve would simply open to supply the deficiency.

It is always possible that a diaphragm may burst causing the valve to be actuated to its wide open position, or a valve may become stuck in a closed or some intermediate position. Reducing pressure valves, as a rule, are reasonably reliable in their performance, but sooner or later something is bound to happen. They will not go on indefinitely without repairs, and if we depend entirely on a single valve, we may expect to have a shutdown, if nothing worse.

The multiple valve proposition has the added advantage that it permits repairs or renewal of parts to a single unit without interruption of service.

From the viewpoints of both safety and service, therefore, the solution is to connect the high and low pressure steam headers together through these multiple nozzles, the combined area of which is sufficient to deliver the maximum weight of steam that must be passed to the low pressure header, and the number of nozzles being such that the failure of a single unit would not entail any disastrous effect on the operating conditions.

This multiple control scheme is no pet theory of the author's, but one that has been worked out to its ultimate conclusions by one of the large central stations and is now in successful operation. This station operates a two pressure system, with extremely wide load variations.

Having determined on the size and number of nozzles, the question of supplying the proper type of reducing pressure valve becomes a comparatively simple one. Reducing pressure valves may properly be divided into three classes, namely, direct acting—in which a balanced pressure valve is controlled directly from a diaphragm, either spring or weight loaded. Pilot operated—in which the valve disc is controlled by a piston through the operation of a diaphragm operated pilot valve. The combination of a balanced lever valve and hydraulic or motor operated regulator.

There are no hard and fast dividing lines between the use of a direct acting diaphragm valve and a relayed operation as embodied in the combination of valve and regulator. Volume requirement and closeness of regulation are the principal factors which determine the one that should be used. As a general rule, it has been found good practice to resort to the relayed operation on sizes above 3 in., especially where high lifts of valves are required for maximum volume requirements.

For reasons too numerous to mention the pilot operated valve should be eliminated from consideration for this service. Such a reducing pressure valve may have its particular fields of usefulness, but this is not one of them.

We think it is generally conceded among engineers that for high pressure and high total temperature, where the volume requirements are such as to call for a comparatively large size valve, the combination regulator is indispensable. The advantage appears to be that a comparatively simple type of balance lever valve can be used, one well adapted to these high pressures and high temperature conditions. It is not necessary that such valves be closely balanced to pressure, as the operating motor of the regulator will have ample power to overcome any reasonable resistance.

Another advantage is that the regulator can be located some distance from the pipe line, where the operating elements will not be subjected to the excessive heat of radiation.

The relay type of pressure control regulator may be defined as a regulator in which variations of pressure, acting on a pressure responsive device, are relayed to a power unit, either fluid pressure or electrically operated, for the operation of the pressure controlling means. More specifically it comprises a power motor, a pressure responsive device, and a pilot valve or a pilot switch, the latter depending upon whether a fluid pressure or electric motor is used.

Now it is obvious that something additional is required in order that the operation of the motor be made to synchronize with that of the pressure device.

The attachment for accomplishing this purpose is generally referred to as the "compensator," the purpose of the compensator being to prevent over-

travel of the motor, which would result in overcorrection of the pressure and hunting action.

Briefly stated, the compensator is any arrangement which will effect a follow-up system of control. The function of the compensator is to cause the operation of the power motor to so react on the pressure device as to change its pressure setting and retard the operation of the power motor, thereby requiring a further operation of the pressure device for a further operation of the power motor.

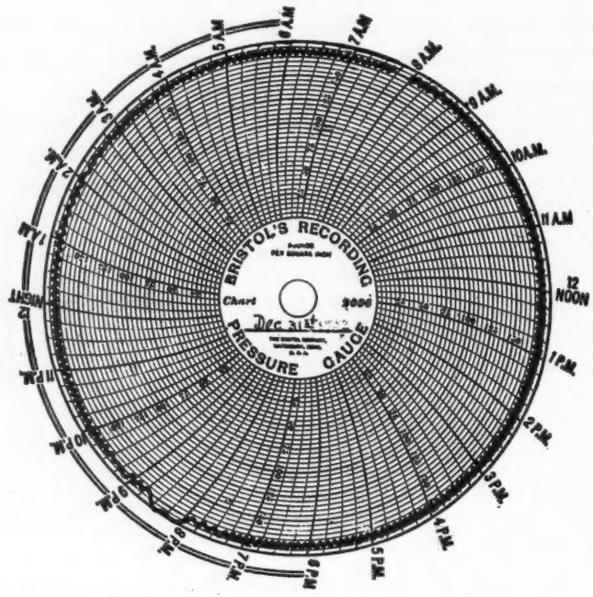


Fig. 1—Chart produced by floating type of regulator of very sensitive action with 3 lb. pressure operating range. The chart shows a consistent pressure fluctuation of 10 lb., with the result that the damper was fully opened and closed 210 times during a period of 24 hours, or about once every seven minutes

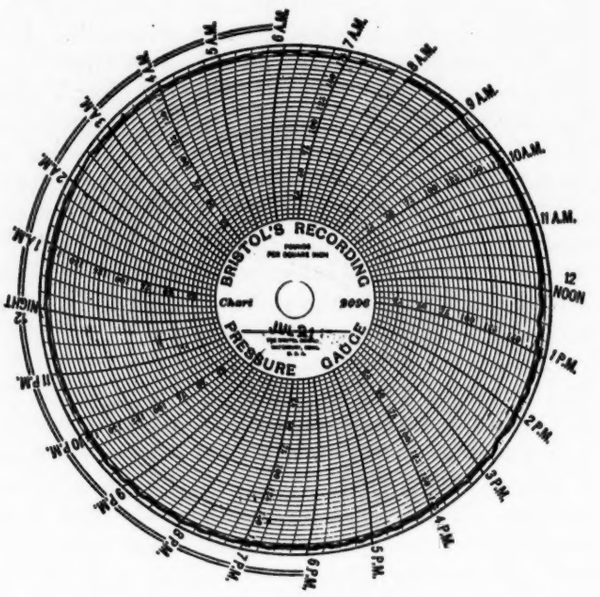


Fig. 2—Chart produced by graduated step action regulator with 12 lb. pressure operating range. As the pressure did not vary more than 5 lb. in 24 hours, the damper was at no time fully opened or closed. This chart was made in the same plant and under the same conditions as that shown in Fig. 1

There is one objection, however, to this type of regulator, namely, "hunting action," which, while it is not inherent in this type of regulator, is made possible through faultily designed control systems.

It is the tendency of the engineer, in specifying reducing pressure valves, to figure too liberally, and as a result, a sensitive regulator of this type never gets a chance to do anything but hunt.

There are two factors which contribute to hunting action:

The first is overtravel, due to the fact that the regulator is not adjusted for sufficient pressure operating range to overcome the unavoidable friction in the pressure device and pilot.

The second is overtravel caused by time lag in the pressure system, which we will hereafter refer to as "pressure-lag."

It will be understood that the result of the overtravel is the same in both cases, namely, hunting action, and the cure for this overtravel is the same in both cases, namely, a wider pressure operating range.

The difference between overtravel, due to avoidable friction, and overtravel due to pressure-lag, is simply this:

In the first instance the power motor is out of step with the pressure device, and in the second instance both the power motor and the pressure device are out of step with the pressure—in either event, hunting action results.

If the conditions are satisfactory; i.e., a mimimun of pressure-lag, the regulator will operate incrementally with a pressure operating range sufficient only to overcome unavoidable friction, or, in other words, the regulator will be self-compensating from pressure changes.

Time lag in pressure control means the time required to correct a change in pressure due to a change in volume demand; obviously, this means time-lag due to slowness of operation of the regulator.

At first thought it would seem as if a rapid-moving power motor was required to minimize the effect of this time-lag, but the trouble is that time-lag works both ways.

While a rapid-moving power motor would be helpful in following up any variation in pressure due to variation in volume demand, at the same time it would, because of its speed, overtravel due to pressure-lag in the pressure system.

From the above it will be seen that the result of changes in regulator settings are not instantly effective at the pressure responsive device, and this is pressure-lag of the system.

Now, as between pressure-lag and time-lag, namely, the time required for the regulator setting to change and the time required before the change

in regulator setting becomes effective at the pressure device, we must strike a happy medium as to power motor speed. While increased speed prevents the pressure getting away from the regulator, on the other hand it results in over-correction, and of the two evils, that which results in overtravel and over-correction is the worse.

From the foregoing, it will be seen that the result of pressure-lag in the system, augmented by over-travel of the regulator, is the most potent factor in producing hunting action. It is one which the manufacturer of regulating equipment cannot control, except by building regulators with the required flexibility of adjustment to meet all ordinary conditions of pressure and time-lag.

The effect of pressure-lag is contingent on two factors, namely, the length of time after a change in volume before a change in pressure becomes effective at the pressure device, and the extent of the change in volume. Or, in other words, the effect of a small change in volume with long pressure-lag is the same as a large change in volume with a small pressure-lag.

I have said the result is the same, but it is only the same insofar as variation in pressure is concerned. The effect on the regulating equipment is quite different. With small time-lag and large volume change, the result is small overtravel with rapid hunting action, while with long time-lag and small volume change, the result is excessive overtravel with a greatly decreased number of operations.

As indicated by a recording pressure chart, the first shows a pressure line with short saw tooth effect, like that in Fig. 1, while in the latter, the cycles of variation cover a much longer period of time, as shown in chart, Fig. 2.

Now in laying out a pressure system, with a view of minimizing pressure-lag and hunting action by the regulator, it must be obvious that the pressure connection to the pressure responsive device should be made as close to the valve as possible, and also that comparatively high velocity flows in the pipe line will help in this respect. And, it must be equally obvious, that the size of the controlling valve should bear a proper relation to the total volume to be passed. It should be understood, however, that where the size of the pipe at the outlet is increased, the diaphragm pressure connection must be made to the large pipe, even though it is some distance from the valve.

If the valve is exceptionally large for the requirements, there will be abrupt pressure changes, and if the pressure connection is taken some distance from the valve then there will be a loss of time before the changes become effective, and the two factors combined spell hunting action.

If the valve is the right size for maximum volume requirement, it will then be the right size for all volume requirements, and there will be no sudden changes in pressure, which can not be compensated for by the regulator.

Should, however, the valve be excessively large for the requirements, we then do not require full travel of the power motor for maximum volume demand, and, consequently, we have cut down the operating time, all of which makes the intermediate steps of operation altogether too abrupt.

Furthermore, these relay types of pressure controls have a certain compensating effect between minimum and maximum travel of the power motor, and if we only use a portion of the total stroke for maximum required volume demand, then we have proportionately cut down the compensating effect, or pressure operating range of the regulator.

The writer's experience with this type of regulator covers a period of nearly forty years, commencing with the advent of the steam turbine, in which the reduction of pressure was then from 200 lb. down to 100 lb. for operating reciprocating engines.

We are again passing through the same cycle, except that the pressure reduction is now from 400 to 600 lb. down to 200 lb. for use with the older type of turbine.

In the olden days, the combination regulator was indispensable for this service. It still is indispensable

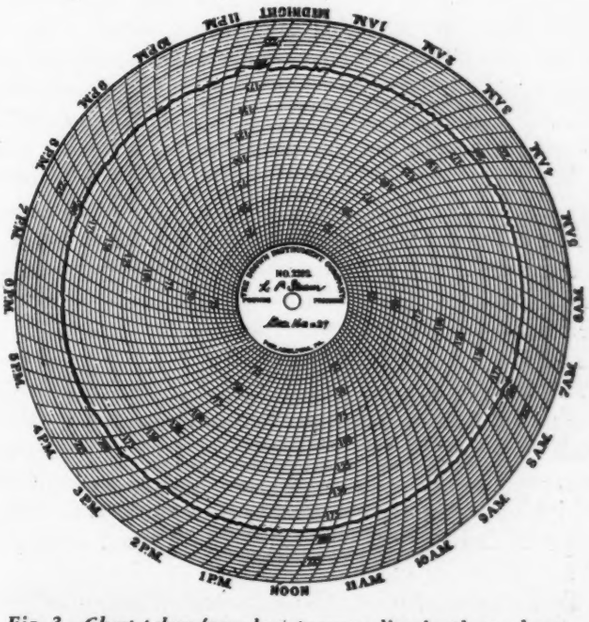


Fig. 3—Chart taken from low pressure line in plant where a reduction from 400 lb. to 190 lb. is secured through the use of three 4 in. reducing valves operating in multiple. The load variation for the 24 hour period covered by the chart was from 45,000 lb. to 300,000 lb.

for our present day requirements, but the greatly increased volume requirements make it desirable to distribute the load among several comparatively small size valves.

Engineering Units

By Wm. L. De Baufre
International Combustion Engineering Corporation, New York

IT WOULD be impossible to make the calculations required in modern engineering work without the units which have been established for measurement of the various quantities involved. In combustion and steam generation, for example, we are concerned with the dimensions of the various parts of the equipment used, with the weight of coal burned, with the volume of air supplied for combustion, with the temperatures of products of combustion and of steam generated, with the pressure of steam, with draft loss, with the heat produced in burning fuel and required in generating steam, with rates of combustion and of heat transfer, with power required for fans, etc. Calculations must be made involving exact relations between all these quantities measured in their respective units.

Engineering units form a part of our everyday working equipment, and like many things that we use more or less familiarly, we understand but little of their fundamental nature and their origin. The author tells the story of these units of measurement in a simple and lucid style, which gives a surprising degree of interest to these commonly used tools without which the engineer would be incapable of functioning.

Various units of length, of volume and of weight have been employed by civilized men at different periods in various countries, and from them have finally been evolved the units in use today. Thus, in the Jewel Tower at Westminster, England, is still preserved the Winchester Bushel measure and the Ale Gallon measure of Henry VII., the Standard Hundred Weight (112 lb.) of Elizabeth and the old Wine Gallon measure of 1707, all of which are shown in Fig. 1. The old Wine Gallon has become the U. S. Standard Gallon of 231 cu. in. In England, the Wine Gallon was abolished in 1824, when the Ale Gallon of Henry VII. was legalized as the Imperial Gallon and its volume fixed at 277.274 cu. in., declared to contain 10 lb. of water at 62 deg. fahr. The present Imperial Standard Yard, constructed in 1844, consists of a bronze bar having a well near each end sunk to the mid-depth of the bar. At the bottom of each well is inserted a gold stud upon which the defining line of the yard is engraved. The Imperial Standard Pound, also constructed in 1844, is a cylinder of platinum.

By measurement of the dimensions of the old Wine Gallon standard measure, its volume was found to be 231 cu. in., thus giving a relation between this arbitrarily selected unit of volume and the arbitrarily determined unit of length. This illustrates the fact that although all units for measuring physical quantities may be arbitrarily selected, there will exist certain definite relations between the various units. By making use of such relations, a complete set of units can be built up from a few arbitrarily defined units. The arbitrarily defined units are called fundamental units, all other units being called derived units. Three fundamental units, length, mass (or weight) and time, are sufficient for problems in mechanics involving velocity, acceleration, force, work, power, etc. For problems in thermodynamics involving heat, a fourth fundamental unit is required, that of temperature.

The present article will discuss the fundamental units and the main units derived therefrom and employed in mechanics; temperature and heat will be considered in future articles.

The metric system represents an attempt to define a set of units simply related one to another and based on certain natural phenomena. This system was devised by a committee of scientists appointed during the French Revolution, and was adopted by the French Republic in 1801.

The Unit of Length.

The unit length of one meter was defined as the one ten-millionth part of the distance from the pole to the equator. This distance had been measured by

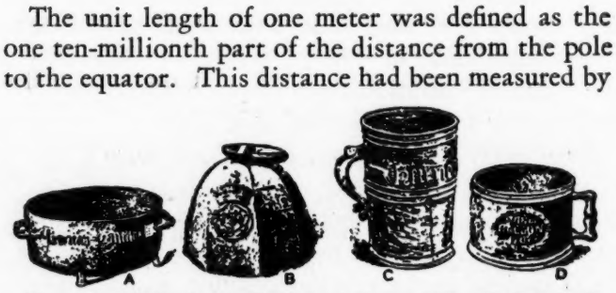


Fig. 1—A, Winchester Bushel of Henry VII.; B, Standard Hundred-weight (112 lb.) of Elizabeth; C, Ale Gallon of Henry VII.; D, the old Wine Gallon. Reproduced from Encyclopedia Britannica

the best means then available and the length of one meter marked on a certain platinum-iridium bar. Subsequent measurements of the meridian have proven that the length of one meter as originally determined is slightly small. Consequently, the idea of making the unit of length bear a simple relation to the circumference of the earth has been abandoned and the meter is now defined as the distance at the temperature of melting ice between two lines on a certain platinum-iridium bar supported at the two neutral points 28.5 cm. each side of the center. This bar is preserved in the vaults of the International Bureau of Weights and Measures near Paris. The United States Bureau of Standards in Washington, D. C., possesses prototypes of this

International Meter, see Fig. 2. The yard is legally defined in the United States as 3600/3937 of a meter instead of being based on the Imperial Standard Yard of Great Britain.

In engineering and scientific conputations, the foot is generally taken as the fundamental unit of length

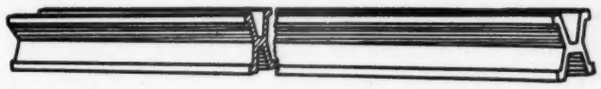


Fig. 2—Prototype of International Meter. Reproduced from U. S. Bureau of Standards paper entitled "History of Standard Weights and Measures of United States"

instead of the yard, and the centimeter is often so used instead of the meter.

The Unit of Mass.

The unit of mass in the metric system was originally intended to be that of a cubic centimeter of water at the temperature of maximum density, 4 deg. cent. A platinum-iridium cylinder was made to represent a mass of one kilogram. As the original measurements were later found to be slightly inaccurate, this unit has been more concretely defined. The kilogram unit of mass is now taken as the mass of a certain platinum-iridium cylinder preserved at the International Bureau of Weights and Measures near Paris. The United States Bureau of Standards possesses prototypes of this International Kilogram, see Fig. 3. "Standard weights" are compared with these prototypes by weighing on an equal arm balance and correcting for the buoyancy of the atmosphere. The pound unit of mass is defined in the United States in terms of the "International Kilogram" according to the relation:

One pound = 1/2.204622 kilogram.

The Unit of Time.

The fundamental unit of time is the second, naturally preserved as 1/86400 of a mean solar day, which is the average throughout a year of the intervals between successive transits of the sun across a given meridian. The apparent solar day is the time interval between any two successive transits of the sun and varies from day to day. Sun dial time corresponds to apparent solar time while clocks and watches show mean solar time. Accurate measurements of time for checking clocks and watches are made by observing successive passages of the vernal equinox (or practically any star) past the meridian. but the time interval so measured is that of a sidereal day and is shorter than a mean solar day by 3 min. and 55.91 sec.

Area and Volume.

The units of area and volume are derived from the fundamental unit of length. Thus, the unit of area is a square having the side of unit length, and the the unit of volume is a cube having the edge of unit length. For measuring liquids and grains, special units of volume are employed, such as

1 U. S. gallon (liquid measure) = 231 cu. in.
(8.34 lb. water at 60 deg. fahr.)

I U. S. bushel (dry measure) = 2150.42 cu. in.

In the metric system, the liter is the unit of capacity and is defined as equivalent to the volume occupied by the mass of one kilogram of pure water at the temperature of maximum density (4 deg. cent.) and under standard atmospheric pressure (760 mm. of mercury). It is equal to 1000.027 cc.

Practically, one liter = 1000 cm^3.
= 0.26418 gal. (about 1/4 gal.)
= 0.028378 bu. (about 1-32 bu.)
= about one qt. (liquid or dry measure)

Let us consider a tank 10 ft. long by 8 ft. wide by 6 ft. deep. It can be demonstrated, of course, that this tank will hold 480 cubes each having edges one ft. long. The usual way to calculate the volume, however, is to write

10 ft. x 8 ft. x 6 ft. = 480 cu. ft.,

the number 480 being obtained by the continued product of 10, 8 and 6. It is convenient to consider the unit of volume, cu. ft. (or $ft.^3$), to have been obtained in a similar manner by the continued product of the three units of length. The combination

Fig. 3—Prototype of International Kilogram. Reproduced from same Bureau of Standards publication as Fig. 2

of units in this way is of great assistance in solving and in checking problems in engineering.

Velocity and Acceleration.

Linear velocity is the rate of change of distance with time. The principal units of velocity are one foot per second (ft./sec.) and one centimeter per second (cm./sec.), obtained by dividing the unit of distance by the unit of time.

Linear acceleration is the rate of change of velocity with time. Dividing the unit of velocity by the unit of time, we find that linear acceleration may be measured in feet per second per second (ft./sec.^{2}), centimeters per second per second (cm./sec.^{2}), etc. The constant acceleration a body would have if free to fall in a vacuum, called the acceleration of gravity, is an important engineering quantity. It varies from place to place on the earth's surface according to latitude and elevation, and even somewhat from one locality to another at the same latitude and elevation. In 1901, the International Committee of Weights and Measures adopted as standard gravity

$$g_o = 980.665 \text{ cm. per sec. per sec.}$$
$$= 32.1740 \text{ ft. per sec. per sec.}$$

This was supposed at the time of its adoption to be the exact value at sea level and 45 deg. north latitude. The standard has not been changed although later observations have shown it to be slightly inaccurate. This standard value should be used in all engineering formulas irrespective of the local value of gravity, for reasons to be given later.

Force and Weight.

Force is a push or pull exerted by one body upon another body. When the metric system of units was devised, it was an accepted fact that an unbalanced force produces an acceleration which is directly proportional to its magnitude and inversely proportional to the mass of the body acted upon. The unit of force was accordingly based upon the three fundamental units of length, mass and time according to the definition: The *dyne* is that unit force which will produce an acceleration of one centimeter per second per second when acting unbalanced upon a mass of one gram. When forces are measured in dynes, we may therefore write

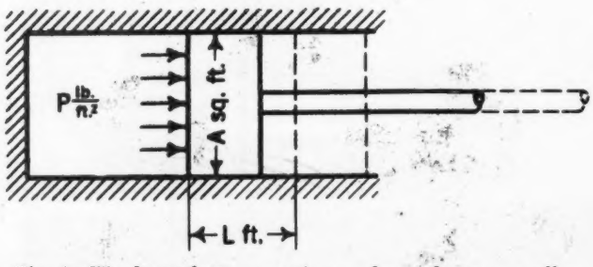


Fig. 4—Work equals pressure times volume change as well as force times distance traversed

$$F = m\,a$$

where F= unbalanced force in dynes,

m = mass in grams and

a = acceleration produced in cm. per sec. per sec.

In order to use the above relation when the mass (m) is measured in pounds and the acceleration (a) is measured in feet per second per second, it has been proposed by many text book writers to employ as the unit of force the "poundal" defined in a similar manner to the dyne. In engineering work, however, forces are usually measured in kilograms or in pounds. The unit force of one kilogram is defined as the pull of the earth upon a mass of one kilogram at the locality of standard gravity. The unit force of one pound may be defined similarly or by the relation:

$$\text{One lb. force} = 1/2.204622 \text{ kg. force.}$$

When forces are measured in pounds or in kilograms, we must write

$$\frac{F}{a} = \frac{W}{g_o} \text{ or } F = \frac{W}{g_o}\,a$$

where F = force in pounds or in kilograms,

W = weight in pounds or in kilograms,

g_o = standard acceleration of gravity, 32.1740 ft. per sec. per sec. or 9.80665 m. per sec. per sec. and

a = acceleration produced in ft. per sec. per sec. or in m. per sec. per sec.

The weight (W) in the above relation is the pull of the earth upon the body at the locality of standard gravity. The weight (W) may be determined in any locality, however, by weighing the body in question on scales calibrated with "standard weights," for the pull of the earth in the locality of standard gravity will be the same for the body weighed as for the "standard weights" which give the same scale reading. Weight has two meanings, namely, "mass" when we are buying or selling materials or are making calculations involving forces in dynes, and "pull of the earth at standard gravity" when we are making calculations involving forces in pounds or in kilograms.

Forces measured by platform scales, spring balances, etc., are somewhat inaccurate because such scales are calibrated and adjusted by use of "standard weights" in the locality where the forces are measured and the local pull of the earth upon the "standard weights" is different from the pull at standard gravity. Such force measurements may be corrected by multiplying the scale readings by the ratio of local to standard gravity. The correction is so small that it is rarely made in engineering work. This is the only use that should be made of the local value of the acceleration of gravity.

Pressure.

The force exerted by one body upon another is

always spread over a certain area of contact. The magnitude of the force per unit area is the pressure, which is accordingly measured in dynes per square centimeter, pounds per square inch, etc. In thermodynamics, we are particularly concerned with pressures exerted by fluids on the walls of containing

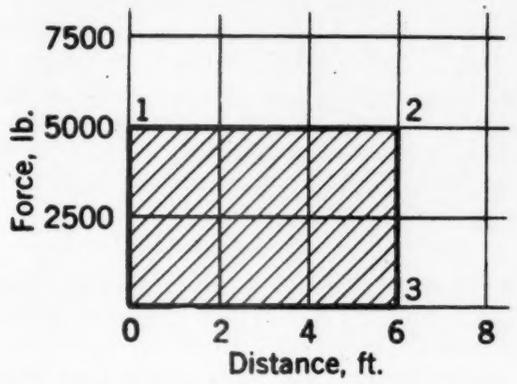


Fig. 5—Work diagram (half size) based on force times distance traversed

vessels. Such pressures are often measured by the head of some liquid which can be supported by the fluid pressure, such as inches of mercury, feet of water, etc. By reason of variation in density of these liquids with changes in temperature, it is necessary to specify some standard temperature or preferably some standard density for each liquid. The standard density internationally accepted for mercury is 13.5951 gm. per cu. cm., equivalent to 0.4912 lb. per cu. in., which represents pure mercury at the temperature of melting ice. Water gage readings are often reduced to 60 deg. fahr. (approximately 15 deg. cent.) at which temperature the density of pure water is 62.37 lb. per cu. ft. Pressures are also measured in atmospheres; but as the pressure of the atmosphere varies from place to place and from time to time, one normal atmosphere has been defined as 760 mm. of mercury at standard gravity and standard density. From the above standards, we derive the following equivalents:

One inch of mercury	= 0.4912 lb. per sq. in.
One inch of water	= 0.03609 lb. per sq. in.
	= 0.07349 in. of mercury
One foot of Water	= 0.4331 lb. per sq. in.
One atmosphere	= 14.696 lb. per sq. in.
	= 29.921 in. of mercury
	= 33.93 ft. of water
	= 1.0333 kg. per sq. cm.

Work and Energy.

Work is done when a force is exerted through a distance, one unit of work being performed when a unit force is exerted through a unit distance. Work is accordingly measured in foot-pounds (ft.-lb.) and in kilogram-meters (kg.-m.). An erg is the work done by one dyne acting through one centimeter. A joule is ten million (10^7) ergs. Work is sometimes measured in liter-atmospheres, one liter-atmosphere being equal to 101.328 joules.

A body is said to possess energy when it is capable of doing work. Energy is therefore measured in the same units as work. A body at rest may be capable of doing work by reason of its elevation above the surface of the earth, its internal strain or some other static condition—in such a state it is said to possess potential energy. A body in motion is said to possess kinetic energy because it is capable of exerting a force F through a distance S in being brought to rest from a velocity V, according to the relation

$$F\,S = \frac{1}{2}\,\frac{W}{g}\,V^2$$

in which W is the weight of the body as determined on scales calibrated with "standard weights" and g is standard gravity. For English units, we have

$$F\text{ lb.} \times S\text{ ft.} = \frac{1}{2}\,\frac{W\text{ lb.}}{g\,\frac{\text{ft.}}{\text{sec.}^2}}\left(V\,\frac{\text{ft.}}{\text{sec.}}\right)^2$$

or

$$F\,S\text{ ft.-lb.} = \frac{1}{2}\,\frac{W}{g}\,V^2\text{ ft.-lb.}$$

Writing in the units as indicated above affords a check upon the proper choice of units and even upon the accuracy of the formula itself, for all formulas should be dimensionally similar on the two sides of the equality sign.

When a fluid expands, work is done against whatever external pressure the fluid may be supporting. Let a piston of area A sq. ft. be moved out a distance of L ft. while a gas exerts a pressure of P lb. per sq. ft. upon the piston as indicated in Fig. 4. The total force exerted upon the piston is $P\,\frac{\text{lb.}}{\text{ft.}^2} \times A\text{ ft.}^2$ The

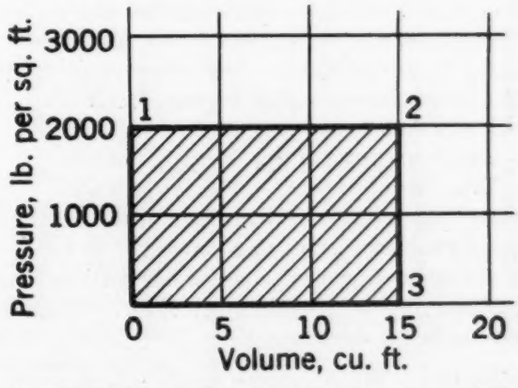


Fig. 6—Work diagram (half size) based on pressure times volume change

work done is equal to this total force multiplied by the distance L ft.; that is,

$$\text{Work done} = \left(P\,\frac{\text{lb.}}{\text{ft.}^2} \times A\text{ ft.}^2\right) \times L\text{ ft.}$$

$$= PA \text{ lb.} \times L \text{ ft.}$$
$$= PAL \text{ ft.-lb.}$$

The above expression can evidently be written

$$\text{Work done} = P \frac{\text{lb.}}{\text{ft.}^2} \times (A \text{ ft.}^2 \times L \text{ ft.})$$

$$= P \frac{\text{lb.}}{\text{ft.}^2} \times AL \text{ ft.}^3$$

That is, the work done in foot pounds is equal to the product of the pressure in pounds per square foot and the volume change in cubic feet as well as to the product of the force in pounds and the distance moved in feet.

Whether considered as force times distance traversed or as pressure times volume change, work may be represented by an area on a diagram. The co-ordinates will be force and distance in one case and pressure and volume in the other case. The scale to which the area represents work will depend upon the scales selected for the co-ordinates. Thus in Fig. 5, a horizontal scale of 1 in. = 2 ft. and a vertical scale of 1 in. = 2500 lb. have been selected, giving an area scale of 1 sq. in. = 2 ft. x 2500 lb. = 5000 ft.-lb. The work done by a force of 5000 lb. acting through a distance of 6 ft. is represented by the shaded area 0123 containing 6 sq. in. equivalent to 6 sq. in. x 5000 ft.-lb. per sq. in. = 30,000 ft.-lb. In Fig. 6, a volume scale of 1 in. = 5 cu. ft. and a pressure scale of 1 in. = 1000 lb. per sq. ft. have been selected. Then 1 sq. in. = 5 cu. ft. x 1000 lb. per sq. ft. = 5000 ft.-lb. Within the shaded area 0123 are included 6 sq. in. representing 30,000 ft.-lb., the work done by a pressure of 2000 lb. per sq. ft. exerted through a volume change of 15 cu. ft.

Power.

Power is the rate of doing work and may be measured in foot pounds per second or in ergs per second. A watt is one joule per second equivalent to ten million (10^7) ergs per second. A kilowatt (kw.) is 1000 watts. One horsepower is equal to the performance of 33,000 ft.-lb. per minute, or 550 ft.-lb. per second. The corresponding metric unit of one cheval-vapeur or one pferdekraft equals 75 kilogram meters per second.

One horsepower (hp.) = 745.7 watts
One cheval-vapeur = 735.5 watts

Two examples will illustrate how units aid in solving problems involving power.

A locomotive exerts a draw-bar pull of 2000 lb. when running at 30 miles per hour. What horsepower is being developed?

$$\frac{2000 \text{ lb.} \times 30 \frac{\text{mi.}}{\text{hr.}} \times 5280 \frac{\text{ft.}}{\text{mi.}}}{60 \frac{\text{min.}}{\text{hr.}} \times 33000 \frac{\text{ft.-lb.}}{\text{min.}} \text{ per hp.}} = 160 \text{ hp. developed.}$$

A waterfall 50 ft. high has a stream flow of 10 cu. ft. of water per second. How much horsepower is this falls capable of producing with an efficiency of 60 per cent?

$$\frac{50 \text{ ft.} \times 10 \frac{\text{ft.}^3}{\text{sec.}} \times 62.37 \frac{\text{lb.}}{\text{ft.}^3} \times 0.60}{550 \frac{\text{ft.-lb.}}{\text{sec.}} \text{ per hp.}} = 4116 \text{ hp. the falls can produce.}$$

It is not usual to write the name of the unit after each figure in a computation as indicated in the above examples, although this often aids in solving such problems. When the answer is obtained, however, the unit should never be omitted. A length of 12 is meaningless, while 12 in., 12 ft. and 12 mi. are all definite values. An abstract number, such as a ratio of two quantities measured in the same units, is the only number which should have no unit written after it.

References.

The reader who is interested in obtaining further information on the historial development of units of measurement, will find interesting reading in the articles on Weights and Measures and on Physical Units in The Encyclopedia Britannica. Glazebrook's Dictionary of Applied Physics contains a good article on Units of Measurement and a full description of Measurement of Pressure. The value of g in engineering and physcial work is discussed by S. A. Moss in the General Electric Review for May, 1918. A more thorough discussion of Mass, Weight and Force is given by the present author in The Journal of Engineering Education for March, 1929.

Seventy Per Cent of American Homes now Wired for Electricity

Figures published in a recent issue of Electrical World indicate that 70 per cent of all the homes in the United States are now wired for electricity. Of the remaining 30 per cent, a large proportion of the homes are in isolated districts.

This is truly remarkable progress when it is realized that as recently as 1917 only twenty-four per cent of the homes in this country were wired. However, we are not so far in the van in this respect; certain European countries are also electrifying at a very rapid rate. In fact the records for domestic electrification in cities are held by Basle, Switzerland and The Hague, Holland, in both of which it is reported that 100 per cent of the homes are wired.

Fuel-generated power continues to gain rapidly on hydro-electric. In 1929, 64 per cent of the electrical output of public utilities was produced by fuel burning plants and 36 per cent by hydro-electric plants.

Another interesting and significant fact is that while there has been an increase of over one hundred per cent in the kw.-hr. production of the past year as compared with 1922, the increase in fuel consumption was only thirty-two per cent. A considerable part of this large economy is due to improvements in fuel burning and steam generating equipment.

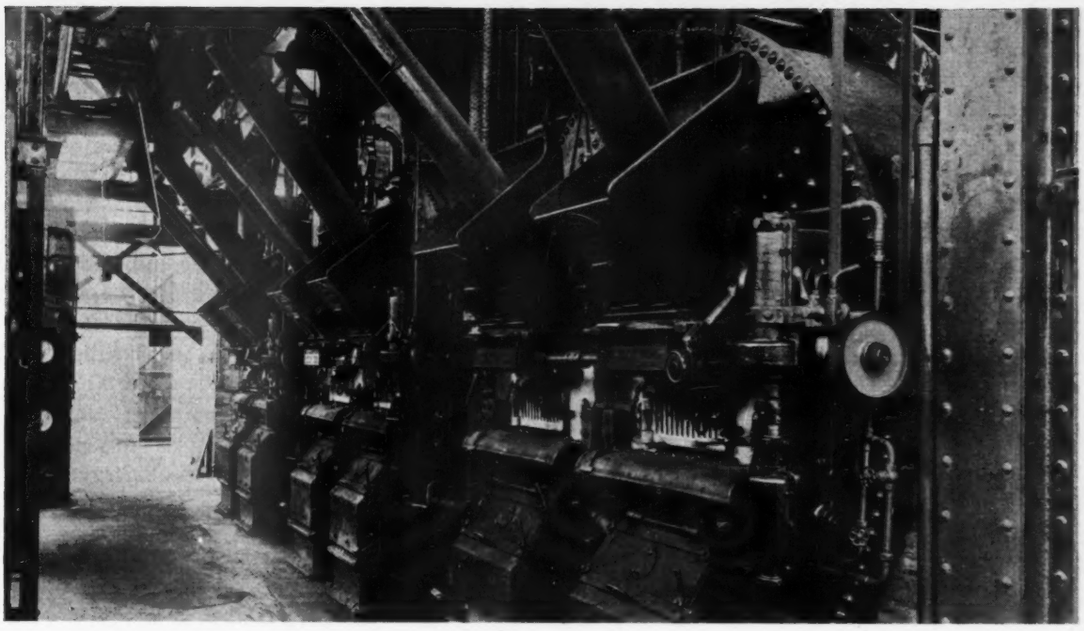


Fig. 1—Installation of Lancashire boilers equipped with Supermiser. Preheated air is admitted through the ducts shown below the stokers

New Developments *in* British Industrial Steam Station Practice

By David Brownlie, London

IT IS well known that for general industrial work the Lancashire internally-fired cylindrical boiler has long reigned supreme in Great Britain, and throughout the British Empire generally. There is much to be said for this practice since under any reasonable conditions, a boiler of this character operates for twenty to thirty years with little or no trouble. Furthermore, fairly high steam generating efficiency can be secured, and relatively little trouble is experienced from breakdown and from the effects of bad feed water.

The normal high grade practice with Lancashire boilers is the use of a unit say 30 ft. long by 8 ft. to 10 ft. dia. having two furnace tubes about 3 ft. 2 in. to 3 ft. 7 in. dia., with any pressure up to 250 lb. per sq. in. gage, and equipped with superheaters and cast-iron feed water economizers. Also mechanical forced or induced draft, steam jet forced draft, air preheating, and mechanical stokers are often included.

In comparing the trends in British and American industrial steam plant practice, we must keep in mind, not only the differing traditions of the art in Europe and America, but the marked differences in local conditions which largely determine prevailing methods and practice. The author of this article briefly reviews British practice and describes two important developments which are finding wide adoption. The efficiency figures given are, of course, based on the European practice of using the net or lower heating value of fuel.

Under these conditions, with accurate control instruments, 75 per cent over-all efficiency can be obtained, with a superheated steam temperature of from 450 to 500 deg. fahr., feed water of from 300 to 320 deg. fahr. with 100 to 120 deg. fahr. entering the economizers, and flue gas temperatures at the base of the chimney down to 350 deg. fahr. The mechanical stokers used are generally of the coking or sprinkling type. Pulverized fuel has so far made little progress in this field, although it is receiving considerable attention now in connection with the analagous Scotch marine boiler which is an internally fired cylindrical unit with three or four furnace tubes and a series of small diameter horizontal tubes in the upper part of the shell.

Although the typical Lancashire boiler plant has become more or less standardized on the lines indicated, steam generation practice does not stand still for long, even in the case of cylindrical boilers. This is well illustrated by two new developments in Great Britain, the Supermiser or combined self contained air preheater and feed water economizer, and the Atkinson rotary grate in which the coal is burned as it rolls around very slowly in a rotating basket or perforated cylinder operating in front of the furnace tubes.

With regard to cast iron economizers, it may be stated that the supremacy of the well known design of smooth vertical cast iron tubes, with scrapers on the outside, introduced nearly 90 years ago, is now being menaced by designs which employ tubes having extended surfaces in the form of gills or fins, and provided with steam jet cleaners to keep the space between the gills or fins free from deposits. In the water tube boiler field the cast iron economizer is also being superseded, not so much by the steel tube economizer—which possesses the serious defect of liability to corrosion—as by the greatly extended use of the air preheater.

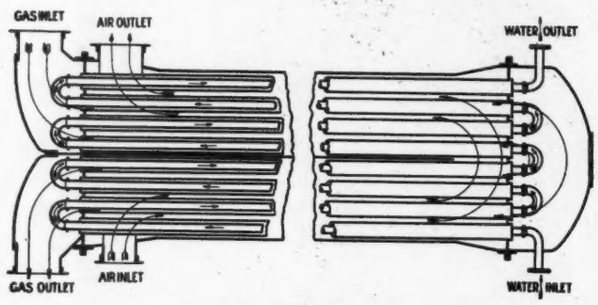


Fig. 2—Sections through the Supermiser, a single unit combining the functions of an air preheater and an economizer

For industrial work and cylindrical boilers the heating of the feed water is vital to efficient recovery of heat in the flue gases, and the Supermiser represents a new method. This is a production (Leek's Patents) of Messrs. Galloways, Ltd. of Manchester, a firm organized over a century ago for the construction and repair of water wheels in the earliest days of the Lancashire cotton industry, before the Watt condensing steam engine became a practical success.

The Supermiser, as shown in Fig. 2, is a combined air preheater and feed water economizer, contained within a horizontal cylindrical steel plate casing through which is passed, by induced draft fans, all the hot flue gases from the boiler. Inside the shell is fixed horizontally a large number of steel tube elements each consisting of an inner tube 2 inches in diameter and an outer tube 4½ inches in diameter. The feed water passes through the inner tubes which are all coupled together at each end by malleable iron headers, so as to give the maximum travel. The outer tubes form an annular space through which the hot combustion gases pass from one end of the cylinder to the other. It will be noted these tube elements are located so as to leave at each end, a large compartment divided off by vertical steel partitions through which all the tubes are fixed. Also there is a horizontal partition, and the flue gases at say 650 to 750 deg. fahr. enter at the top at one end, pass along the upper half of the nest of elements between the inner and outer tubes, and then back again through the lower half of the tubes, with final discharge from the bottom to the chimney at say 250 to 300 deg. fahr.

The large inner compartment formed by the elements and the two end partitions constitutes the air preheater, the cold air for combustion passing in by means of a forced draft fan at the bottom and travel-

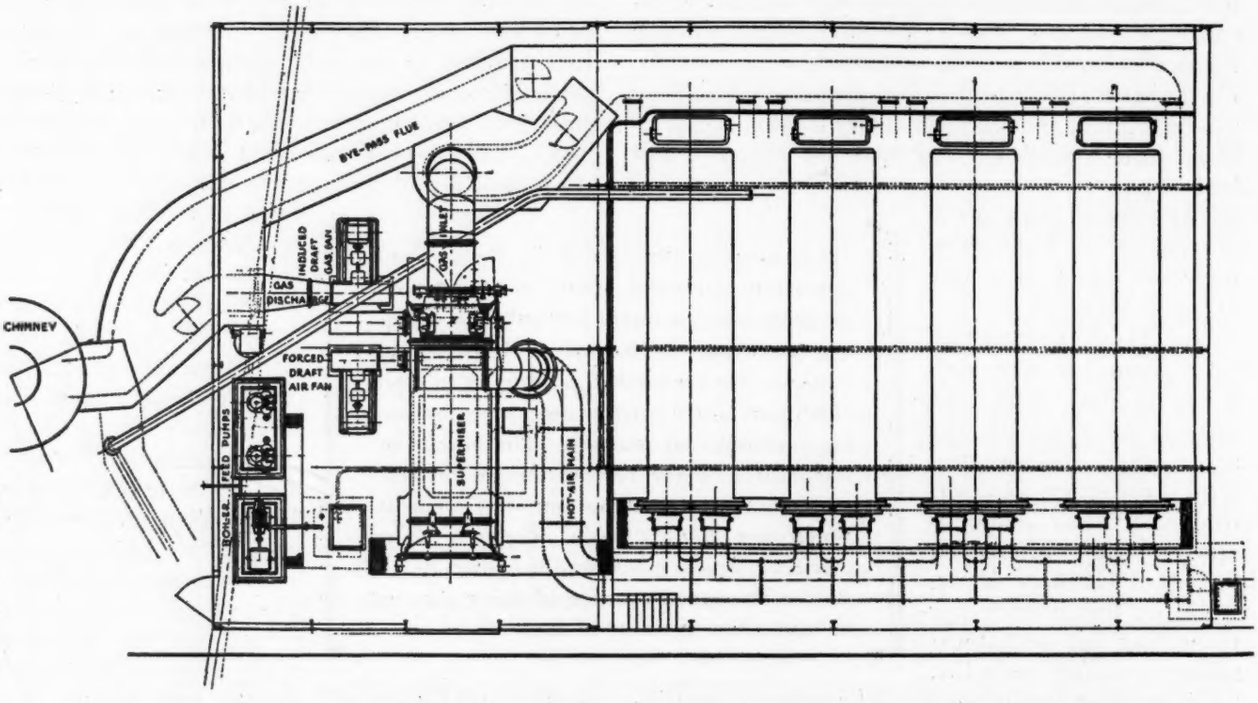


Fig. 3—Plan view of a plant consisting of four Lancashire boilers equipped with Supermiser. The Supermiser installation is shown on the left

ing over the outside of the heated tubes, first horizontally for the full length in one direction, because of suitable baffles, and then back again along the top, with discharge at about 250 to 300 deg. fahr. to the duct leading to the combustion chamber. The feed water enters the inner tubes at the bottom and leaves at the top at a temperature of about 280 to 320 deg. fahr. An important feature is that the heating gases, the air for combustion, and the feed water all travel through their respective circuits at high speed

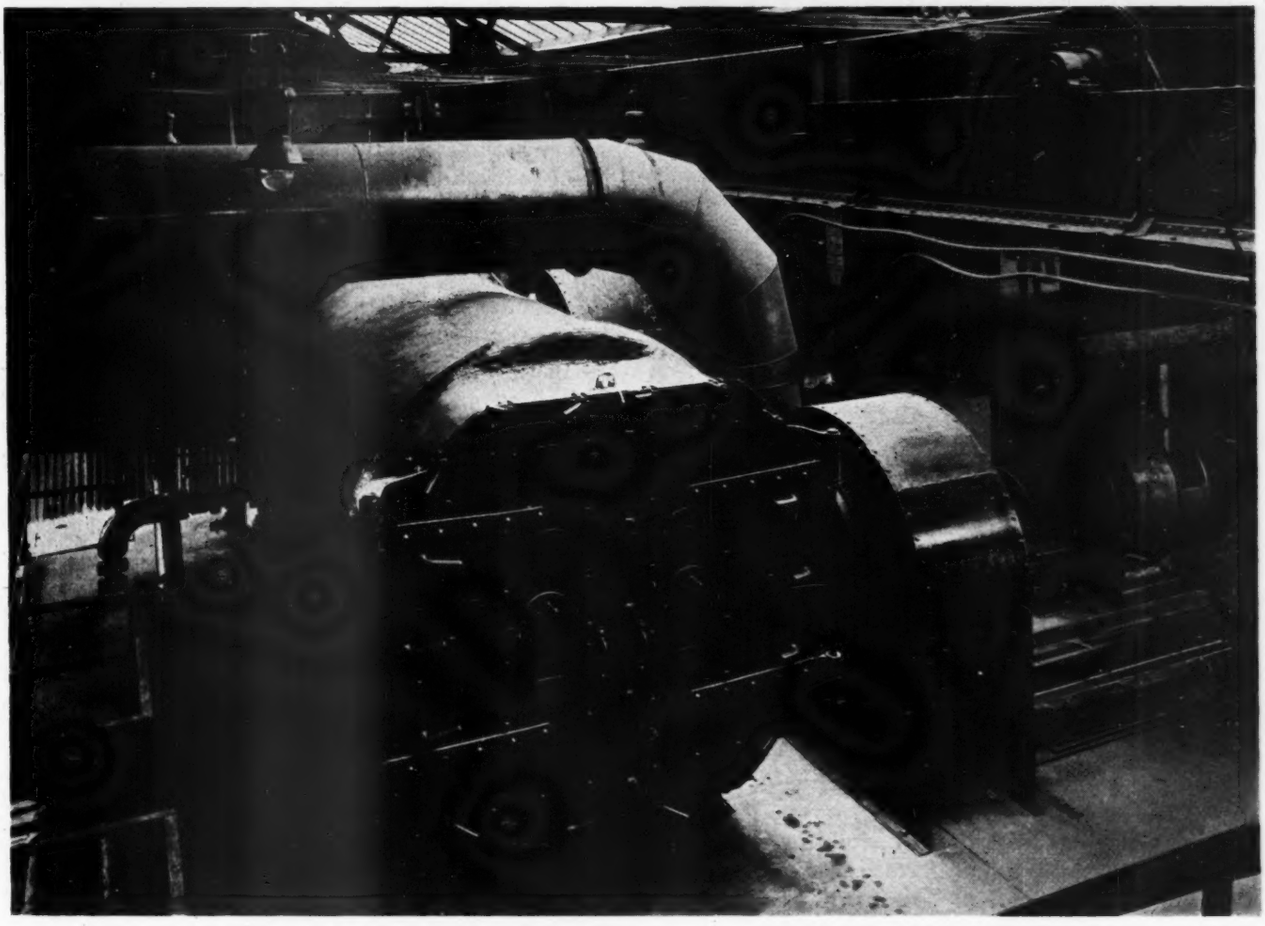


Fig. 4—Supermiser installation in the plant of the Consett Iron Company, Ltd., Durham

to increase the rate of heat transmission from the combustion gases in the concentric space to the cold water in the inner tubes and to the cold air outside.

A typical installation of four Lancashire boilers is illustrated in Fig. 3. This is a plan view with the Supermiser on the left, including forced and induced draft fans, ducts, bypass flue and chimney. A considerable number of these Supermisers are now in service in Great Britain. Fig. 4 shows an installation at the angle rolling mills of Messrs. The Consett Iron Co., Ltd., Durham. This consists of three Galloway (Lancashire) boilers 30 ft. x 9 ft. operating at 160 lb. pressure with 120 to 150 deg. fahr. above saturation temperature for the superheated steam, and one Supermiser with all accessories, including completely automatic regulation for the fans and mechanical stokers required by the violent fluctuations in the demand for steam characteristic of a rolling mill, as well as steam soot blowers and a lime and soda ash water softening plant. The general operating conditions are 300 deg. fahr. in the base of the chimney, 300 deg. fahr. in the preheated air, and also 300 deg. fahr. in the feed water, raised from 150 deg. fahr., with an evaporation of 30,000 to 33,000 lb. of water per hr. for the three boilers, which figures, of course, indicate performance far superior to average Lancashire boiler practice.

One special test carried out upon a Supermiser installation at a colliery belonging to the Wigan Coal and Iron Co., Ltd., by the National Boiler and General Insurance Co., Ltd., Manchester, showed that a net over-all steam generation efficiency of 83.1 per cent was obtained after deducting the power used by the fans, the gross figure being 85.04 per cent. The water evaporated for a single Lancashire boiler was 8361 lb. per hr. with cold air inlet 61 deg. fahr., preheated air outlet 363 deg. fahr., cold feed water 115 deg. fahr., hot feed water 284 deg. fahr., flue gases from boiler 786 deg. fahr., and chimney gases only 246 deg. fahr.

It is claimed that dust troubles do not take place because of the high velocity. The malleable iron headers are easily removed for inspection by unscrewing a single bolt. However, both mechanical forced and induced draft, and water softening plant must be used, and under these conditions the ordinary air preheater and feed water econmizer plant gives

Fig. 5—Typical installation of the Atkinson Rotary Furnace in which coal is burned as it rolls around in a slowly rotating cylinder

excellent results, although occupying much more room.

The Atkinson rotary furnace, shown in Figs. 5 and 6, consists essentially of a slightly inclined, rotary perforated cylinder, formed of special cast iron firebars, which is fixed in front of the boiler furnace tube or other furnace setting, and driven at an extremely slow speed by gearing. In this cylinder the coal is burned, the fire occupying about one-third of the total cubic capacity of the cylinder, and being continually "sluiced" around, that is, piling up at one side and rolling back again giving a thorough mixing. The coal is fed continuously at any desired rate to the open front of the rotating cylinder, which is contained within a stationary casing, by means of a screw feed conveyor fixed horizontally across the front at the lower portion. The air for combustion is delivered by ducts to the side of the casing, and by suitable partitions is made to enter the cylinder between the bars and beneath the fire, which always occupies relatively the same position in spite of the rolling and tumbling of the constituent portions. The flames pass out of the opposite end into the boiler furnace tube, each of which has its own cylinder, that is two units side by side for a Lancashire boiler. The ash and clinker fall through the bars and are removed from the end of the cylinder into a lower part of the casing. Fig. 5 shows a typical installation of an Atkinson rotary furnace at Warrington.

In Fig. 6, (a) indicates the main air supply trunks with control slides (b) and auxiliary trunks (c) connecting to the cylinders (d) with internal baffles (e) to deflect the air, while a steam blast can be admitted at (f). The pinion (g) drives a large outer gear wheel of the combustion cylinder, while (h) is the screw feeder for the coal and (i) the ash pit door.

It is claimed that the results obtained are of greatly improved character as compared with the ordinary hand fired grates or mechanical stokers for cylindrical boilers, especially with regard to the amount of coal consumed per hour, as high as 150 lb. per sq. ft. of effective grate area, and the over-all thermal efficiency. These advantages are magnified in the case of difficult low grade fuels, the main point being that because of the slow agitation of the charge and the intimate mixing of the fuel with the air, the combustion is much more uniform and rapid. Furthermore, the flames and combustion gases are given a twisting action, while the excess of air required above the theoretical is considerably reduced.

As typical of the results obtained the following figures are given for detailed tests carried out in

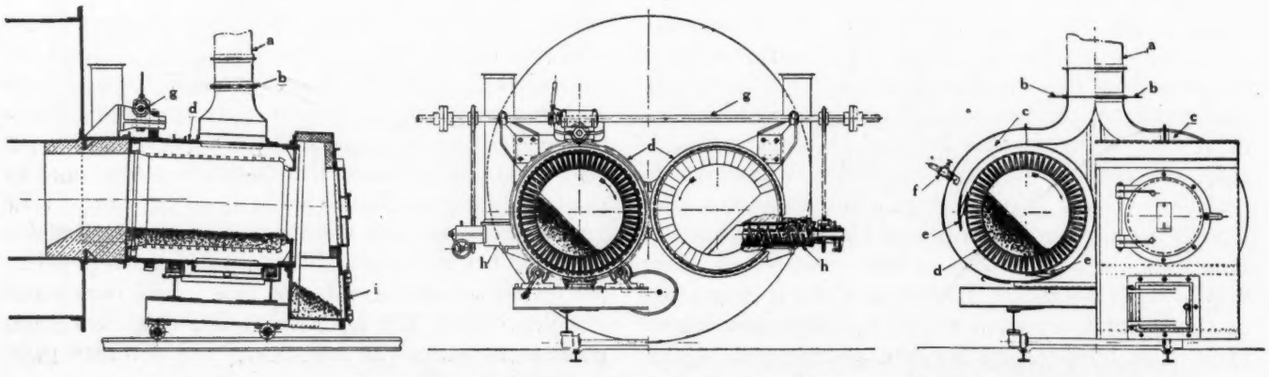


Fig. 6—Sections and elevations of the Atkinson rotary furnace as applied to standard Lancashire boilers

November, 1929, on a rotary furnace installation operating a standard Lancashire boiler with superheater, but no feed water economizers:

	Test No. 1 Nov. 13-14 1929.	Test No. 2 Nov. 18-19 1929.
Duration Hours.	24.58	21.00
Coal Used.	Lancashire bituminous Pemberton.	Ackers-Whitley-5 ft. seam.
Total Coal burned. lb.	25,984	20,272
Coal burned per hour. lb.	1056.9	965.3
Total water evaporated. lb.	185,725	143,260
Water evaporated per hour. lb.	7555	6822
Steam pressure. lb. gage.	207	198
Temp. of superheated steam	458 deg. fahr.	452 deg. fahr.
Temperature of feed water	135 deg. fahr.	128 deg. fahr.
CO_2. in flue gases	14.2 per cent	not stated.
Lb. of water evaporated per lb. of coal	7.147	7.067
Lb. of water from and at 212 deg. fahr. evaporated per lb. coal.	8.389	8.332
Heating Value of Coal. B.t.u. per lb.	11225-11636	11049-12050
Thermal Efficiency, Boiler and Superheater	71.15 per cent	73.18 per cent
Thermal Efficiency, calculated if economizers were included	79.01 per cent	81.22 per cent

While, as already stated, Lancashire boilers can be operated at efficiencies as high as 75 per cent even with hand firing, providing all conditions of operation are ideal, the average results are about 65 per cent thermal efficiency (for boilers, economizer and superheater), 6500 lb. evaporation per hr. (30 ft. x 8 ft. boiler), 6.5 lb. of water evaporated per 1.0 lb. of coal, and 8.5 per cent CO_2. The test figures given, therefore, represent remarkable results for this type of boiler plant.

The Atkinson rotary furnace was introduced for burning general household refuse and the first experimental installation in this connection was for the Glasgow Corporation. The cylinders for this service were of much greater length (about 15 ft. 9 in. with a diameter of 3 ft. 6 in.) than those later used for boiler operation. As a result of this experience other fuels were used, especially low grade coke breez mixed with small sized coal, and it was discovered that very high rates of combustion could be obtained, with as much as 16 to 17 per cent CO_2 in the flue gases. Accordingly, a number of Lancashire boilers were equipped experimentally and the apparatus modified by experience until the present standard design was adopted. The average length of the rotary cylinder is now 4 ft. 6 in. and the diameter 2 ft. 6 in. (internal dimensions), while the speed is one revolution in about three or four minutes, but varied as required.

In general the advantages claimed for the Atkinson rotary furnace are 75 to 80 per cent thermal efficiency for Lancashire boiler plant (boilers, economizers and superheaters) burning ordinary slack, with 50 per cent more evaporation than normal. For purely refuse fuels of 6000 B.t.u. per lb. or less, difficult to burn by any ordinary methods, the corresponding figures are 65 to 70 per cent thermal efficiency and an evaporation equal to that which can be secured with ordinary slack.

Messrs. Stein & Atkinson, Ltd., have recently developed this rolling, mixing and sluicing action of the fire particularly as applied to lower grade fuels, for water tube boilers. A special type of endless chain grate, shown in Fig. 7, is used and is now operating in Glasgow, burning wood chips, sometimes mixed with coal. This design has since been

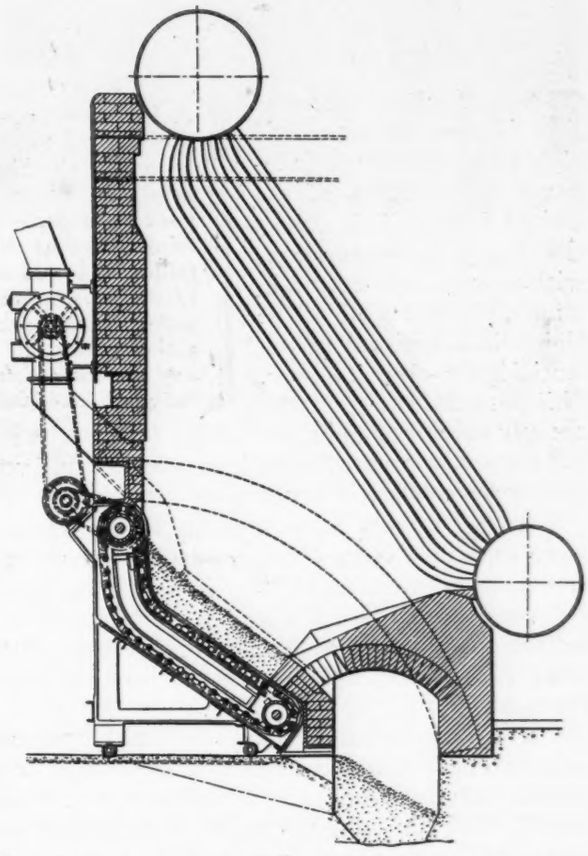


Fig. 7—Section through Atkinson endless chain grate stoker for water tube boilers

modified slightly, but in general the raw fuel is fed in at the top by means of a variable speed rotary feed drum divided into compartments, and burns in the sharply inclined fire which is caused to move downwards, with mixing action by the endless chain grate, varied in speed as required. With normal forced draft it is claimed that as much as 150 lb. of fuel per sq. ft. of grate area per hr. can be burned.

The author extends his thanks to Messrs. Galloways, Ltd., Knott Mill Ironworks, Manchester, and Messrs. Stein & Atkinson, Ltd., 47 Victoria Street, Westminster, London, S.W.I, for kind assistance, including drawings and photographs.

UNUSUAL STORIES FROM THE FIELD

This page is devoted to stories of unusual happenings which test the reserve resources of men and equipment

Airplane Carrier Lexington Helps Tacoma Meet Power Emergency

By A. F. DARLAND

Superintendent of Electrical Design and Construction, Department of Public Utilities, City of Tacoma

A few weeks ago the newspapers featured the story of the Navy Department's action in sending the airplane carrier Lexington to help the city of Tacoma in meeting its power emergency brought about by lack of rainfall in the Northwest and consequent failure of hydro-electric power. The details of the situation are given in this interesting article. In the concluding paragraph the author points out that plans are now under way for the construction of a steam station for peak load and standby service.

THE Pacific Northwest is generally considered to be one of the heaviest rainfall sections of the United States. This condition has made Washington, with her two lofty mountain ranges, the first State of the Union in magnitude of potential hydro-electric power. This potential energy can be cheaply developed and there has naturally resulted electric power systems very largely hydro-electric in character.

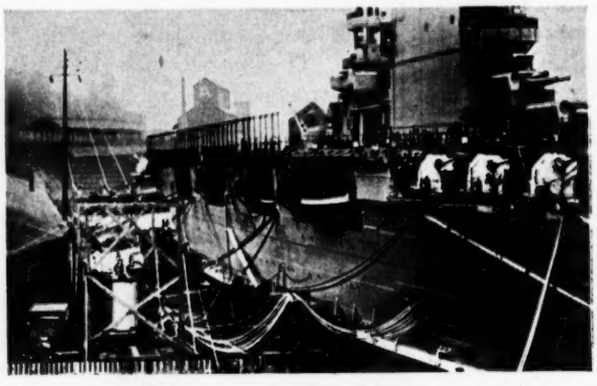
The 1929 drought in the Northwest, the worst in more than fifty years of local weather records, has convinced even the staunchest supporters of hydro-electric systems in this district that the hydro-electric station must be more liberally supplemented by steam electric power plants than has heretofore been the case.

The electric utilities supplying Tacoma, Seattle and the Puget Sound District were confronted with streams greatly shrunken by the almost total failure of Fall rains, throwing the burden of the system load upon the hydro plants having water storage and such steam plants as are available. By the middle of December continued drought had caused the almost complete depletion of the water storage but at that time, abundant rains brought relief for the stream flow plants.

Tacoma's system consists of two hydro-electric stations, aggregating 60,000 kw., and a steam plant of but 9,000 kw. The Cushman No. 1 hydro-electric plant of the City has a storage capacity of 440,000 acre-feet, the largest in the district, and it is this storage that suffered most and will require longest to be replenished. The average annual rainfall at the power house above which this storage is located is 100 inches. The year 1928 had but 78 inches of rain at this point while the twelve month period from December 1, 1928 to December 1, 1929 produced a rainfall of only 30 inches.

When it became evident that the rainfall shortage was extending to drought proportions, a number of privately owned plants, with which the City has reciprocal contracts, were put into service. In order to secure further relief, in the event that the drought extended beyond the time when all stored water would have been used, consideration was given to a suggestion made by an employee of the City Utilities Department that the use of naval craft having suitable generating capacity be arranged for in order to augment the City's facilities.

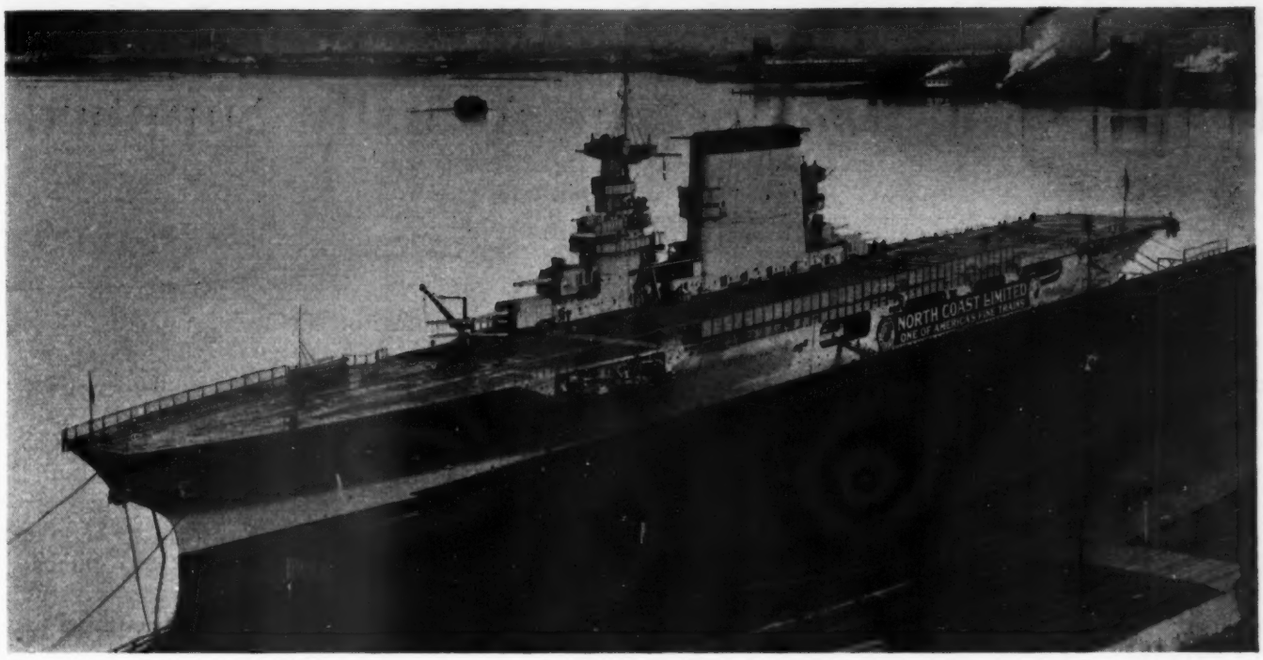
The airplane carriers Lexington and Saratoga were both at the Puget Sound Navy Yard at Bremerton, Washington undergoing repairs. Each of these ships



View showing lines from ship connecting to two transformers on dock

is equipped with four 40,000 kw. turbo-generators suitable for operating at a maximum speed equivalent to 60 cycles, and adaptable in general design for connection to shore stations.

Application for the use of one of these ships was formally made by Mayor Newbegin of Tacoma to Secretary Adams of the Navy on November 16, 1929.



U.S.S. Lexington tied up at Ocean Dock in Tacoma

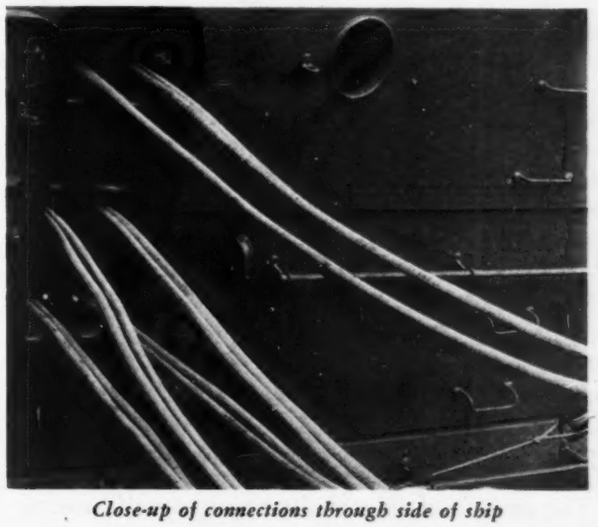
Investigations were made by the Navy Department to ascertain docking facilities for the ship, the necessity of loaning the ship for the service proposed and the probable time that it would be required. Final consent for the use of the airplane carrier Lexington was granted December 12, the ship was moored to the dock December 15 at 2 p. m. and the 20,000 kw. service connection to the ship generators was completed and put into service on the evening of December 17.

The physical problem of berthing the ship was one of major proportions in that the ship has a normal draft of thirty-three feet and must have an additional depth of water sufficient to prevent the suction of mud into the cooling intake near the ship's keel. The problem was solved by breasting the ship out from the ocean dock in Tacoma's harbor to a point where a depth of eighty feet was available. This was accomplished through the use of a number of barges each thirty feet wide. Electrical connection was then made by means of two 750,000 circular mill conductors per phase to the three phase circuits supplying one of the main propulsion motors. Two transformer banks, each of 10,000 kva. capacity, 4,620 volts to 52,000 volts, were placed on railroad cars located on the dock opposite the ship. Leads through the skin of the ship were carried over supporting floating trestles through circuit breakers and thence to the transformers. Connections to the 50,000 volt net work of the City required the building of approximately two miles of three phase, 50,000 volt circuit through residential streets.

The Lexington has supplied a demand ranging from 9,000 to 20,000 kw. Energy has been supplied over the peak loads only, so that the actual energy consumption has been rather small. This consumption has averaged about 150,000 kw.-hr. a day.

During the thirty day period that the ship was loaned to the City of Tacoma it was stipulated by the Navy Department that energy supplied from the ship was to be used for the sole purpose of conserving water at the No. 1 Cushman Plant. This storage has increased since the arrival of the Lexington in an amount equivalent to eight million kw.-hr. which is ample to meet load requirements during a year of normal rainfall.

Tacoma's third hydro-electric plant, Cushman No. 2, is now under construction and it is expected to be in service in the fall of 1930 with an initial rated capacity of 54,000 kw. making a total of 114,000 kw. installed hydro capacity. The first unit of a steam electric station of 25,000 kw. capacity is planned for construction in the near future and will be used for peak load service and as a standby.



Close-up of connections through side of ship

How *to* Calculate *the* Air Required *for* Combustion *and the* Air Actually Supplied

By B. J. Cross

Combustion Engineering Corporation, New York

THE air required for the combustion of a fuel may be calculated from its chemical analysis. The only combustible elements in fuel are carbon, hydrogen and sulphur. These elements combine with oxygen in definite proportions according to the following equations:

1. $C(12) + O_2(32) = CO_2(44)$
2. $2H_2(4) + O_2(32) = 2H_2O(36)$
3. $S(32) + O_2(32) = SO_2(64)$

The numbers in the parentheses are the molecular weights times the number of molecules involved and represent the combining proportions by weight of the elements. Thus, in equation 1, twelve parts of carbon combine with thirty-two parts of oxygen to form forty-four parts by weight of carbon dioxide.

From the three equations given above it may be seen that for complete combustion, 1 lb. of carbon requires 2 2/3 lb. of oxygen; 1 lb. of hydrogen requires 8 lb. of oxygen and 1 lb. of sulphur requires 1 lb. of oxygen. When the percentage of each of these elements in the fuel is known, the total oxygen required for the combustion in 1 lb. of fuel may be easily calculated. As all fuels contain some oxygen, its amount must be subtracted from the calculated amount to get the oxygen that must be supplied for 1 lb. of fuel.

The source of oxygen for combustion is the atmospheric air. Air contains by weight 23.19 per cent of oxygen, the remaining 76.81 per cent being nitrogen and other inert gases. Thus, for every pound of oxygen supplied for combustion we must accept the accompanying 3.31 lb. of nitrogen, or to get 1 lb. of oxygen we must take 4.31 lb. of air. The amount of oxygen as calculated for 1 lb. of fuel multiplied by 4.31 will give the amount of air theoretically required per pound of fuel.

The following table gives an example of the calculation of the air required for a bituminous coal.

Element	*Per Cent*	*Weight-lb. per lb. fuel*			*Oxygen Required-lb.*
Carbon	74.0	.740	× 2 2/3	=	1.975
Hydrogen	4.8	.048	× 8	=	.384
Oxygen	6.0	.060			
Sulphur	2.5	.025	× 1	=	.025
			Total oxygen		2.384
			Less oxygen in fuel		.060
			Net oxygen required		2.324

Theoretical air required for combustion 10.02 lb.

The amount of air actually required will be somewhat in excess of the theoretical amount. If only the theoretical amount of air were supplied, part of the combustible would pass out of the furnace unburned and a high heat loss would result. If excess air is supplied so that all of the combustible would be burned, an excessive loss due to the large amount of hot flue gases discharged to the stack would result. A compromise must, therefore, be made and the amount of air supplied should be adjusted to give the lowest combined loss due to unburned combustible and excess air. Usually from 20 to 50 per cent of air in excess of that theoretically required is supplied.

The amount of air supplied per pound of fuel may be determined from the flue gas analysis. If all of the nitrogen in the flue gases came from the air supplied, the amount of air could be calculated directly. However, as all fuels contain nitrogen, some of them in considerable amount, the air supplied for combustion is best determined by a more indirect method.

The dry gas per pound of fuel is first computed by the equation:

$$\text{Dry gas} = \frac{4CO_2+O_2+700}{3(CO_2+CO)} \times Cb$$

This equation was developed and explained in the first article of this series.

The total flue gas per pound of fuel is then determined by adding to the dry gases, the amount of moisture in the fuel and that formed from the burning of the hydrogen in the fuel ($9 \times H_2$).

As the total gas per pound of fuel consists of the air supplied plus the fuel gasified or burned, the air may be determined by substracting from the total weight of gases per pound of fuel, the weight of the fuel minus the unburned portion or

Air supplied = total gas per pound of fuel—
[1—(Ash plus carbon in ash)]

The air supplied for a number of typical fuels has been calculated for varying amounts of excess air and is shown by the curves of the accompanying chart. In order to make these curves more widely applicable, the fuels have been assumed moisture and ash free. The results obtained from the curves must be multiplied by (1—moisture and ash), for specific fuels. Curves for the CO_2 per cent of the flue gases as varying with the amount of air used are also shown on the chart. The correction for moisture and ash does not of course apply to the CO_2 curves.

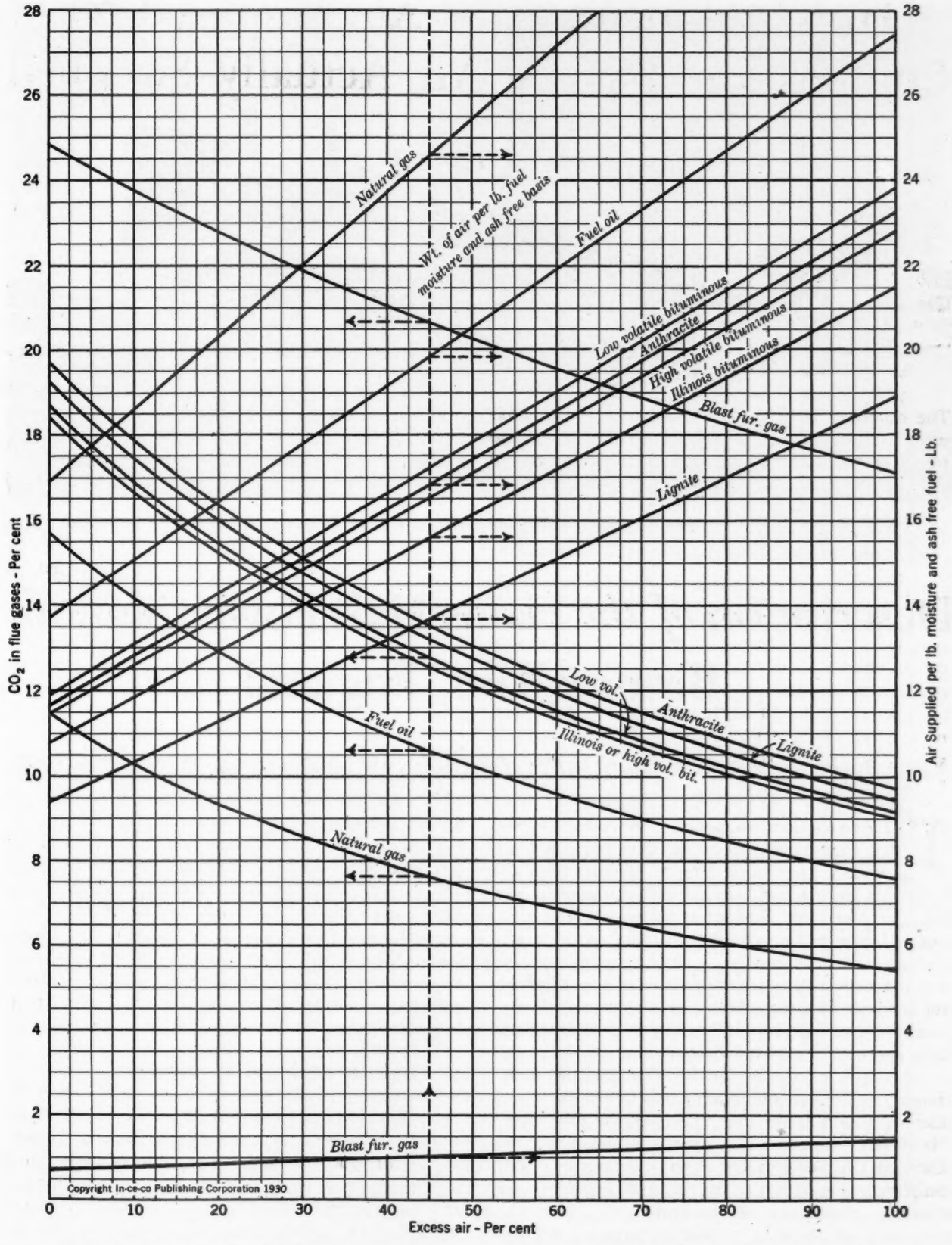
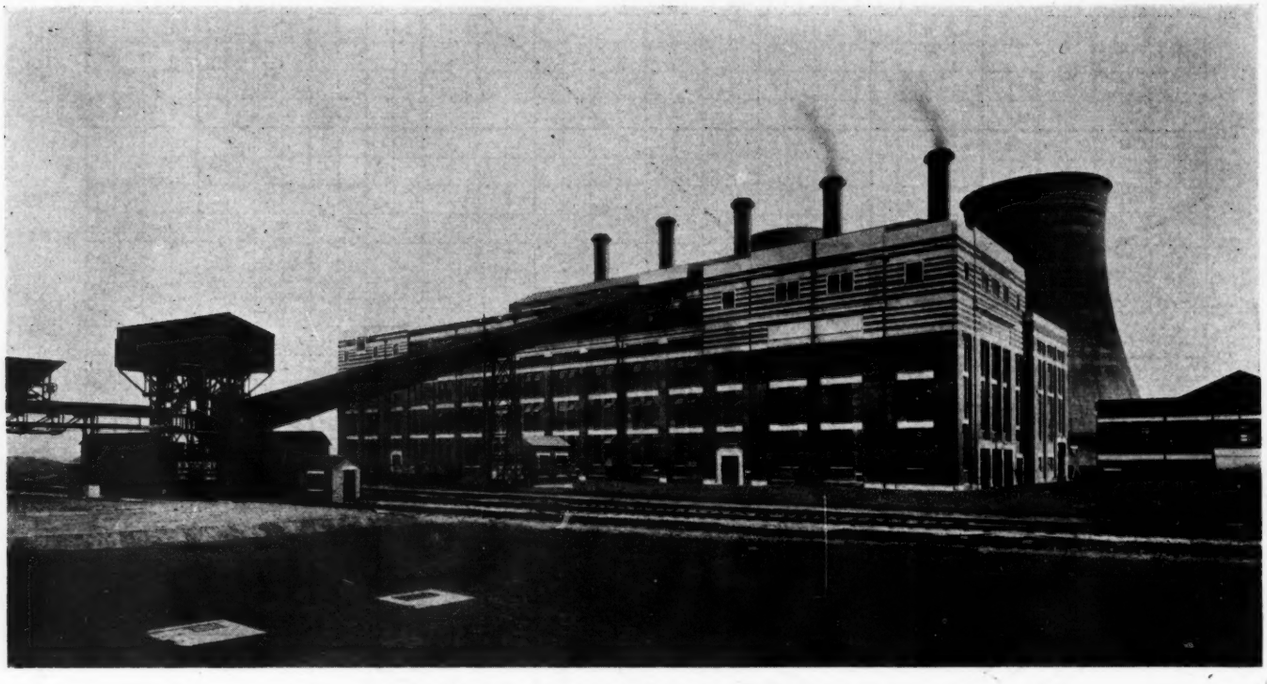


CHART FOR DETERMINING THE AIR REQUIRED FOR COMBUSTION AND THE AIR ACTUALLY SUPPLIED

No. 7 of a series of charts for the graphical solution of steam plant problems



Photograph of recently completed Hams Hall Power Station

Description *of the* Hams Hall Power Station, Birmingham, England

A new British power station, the first section of which was placed in operation in November, 1929.

THE first section (60,000 kw.) of the new Hams Hall Power Station of the Birmingham Corporation Electricity Supply Department, designed for 210,000 kw., was officially opened by the Duke of York on November 6, 1929. The site, acquired by the Corporation as long ago as 1919, is about 3½ miles northeast of the city boundary, near the Coleshill Station of the London Midland and Scottish Railway. This site is conveniently situated for the delivery of coal by rail since it adjoins the main line from Birmingham to Derby.

The complete contract for the entire station, foundations, buildings and plant, was given to International Combustion Ltd., London, in July 1927. The other companies installing equipment as described in this article acted as sub-contractors. The cost for the initial 60,000 kw. section, including the necessary provisions in building, etc., for the immediate addition of a further 30,000 kw., was approximately $6,490,000. The estimated cost of the completed station of 210,000 kw. is approximately $17,000,000.

The coal is weighed as it is delivered, and dumped into a hopper from which it can be taken either to the storage pile of 27,000 tons capacity or direct to the overhead hoppers of the station. In the latter case it is carried by bucket elevators to long inclined belt conveyors going to the roof of the boiler house where it is transferred to two distributing belt conveyors each with a capacity of 100 tons of coal per hour. Coal delivered to the storage pile is taken from the unloading hopper by belt conveyors and distributors, the installation including a Priestman steam grab crane, manufactured by J. M. Henderson Ltd., with a working radius of 60 ft. The coal handling equipment was supplied by the Mitchell Conveyor and Transporter Co. Ltd.

The boiler house is 375 ft. long by 85 ft. wide by 80 ft. high and contains five Babcock and Wilcox boilers of the sectional header marine type. Each boiler has 20,000 sq. ft. of heating surface, with superheater surface of 4566 sq. ft. and is designed for 190,000 lb. evaporation per hr. normal duty and 228,000 lb. overload, operating at 375 lb. pressure, 295 deg. fahr. water temperature and 710 deg. fahr. final steam temperature.

The boilers are installed over Lopulco pulverized fuel furnaces, each of 14,000 cu. ft. capacity equipped

with fin-tube water cooled side and rear walls, totalling 2122 sq. ft. of heating surface, and water screens of 360 sq. ft. of heating surface. Each furnace is fired by five Lopulco turbulent burners with a normal capacity of 3 tons of coal per hr. per burner.

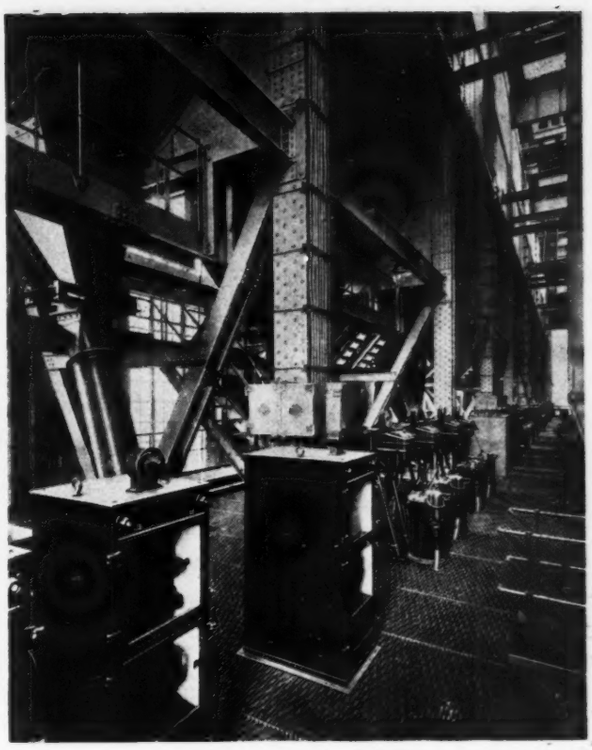
The pulverized fuel system is of the direct fired type using Atritor unit pulverizers with one pulverizer to each burner or five pulverizers per boiler. The pulverizing mills have a maximum hourly capacity of four tons of low grade coal running 25 per cent moisture and 20 per cent ash, and grind to a fineness of 63 per cent through a 200 mesh screen.

The fans and dust collectors were supplied by Davidson and Co. Ltd., each boiler having a 40 in. double Sirocco fan driven by a d.c. variable speed motor with a speed range of from 380 to 620 r.p.m. Air for combustion passes through a Usco multiple plate air preheater of 40,800 sq. ft. heating surface, supplied by the Underfeed Stoker Co. Ltd.

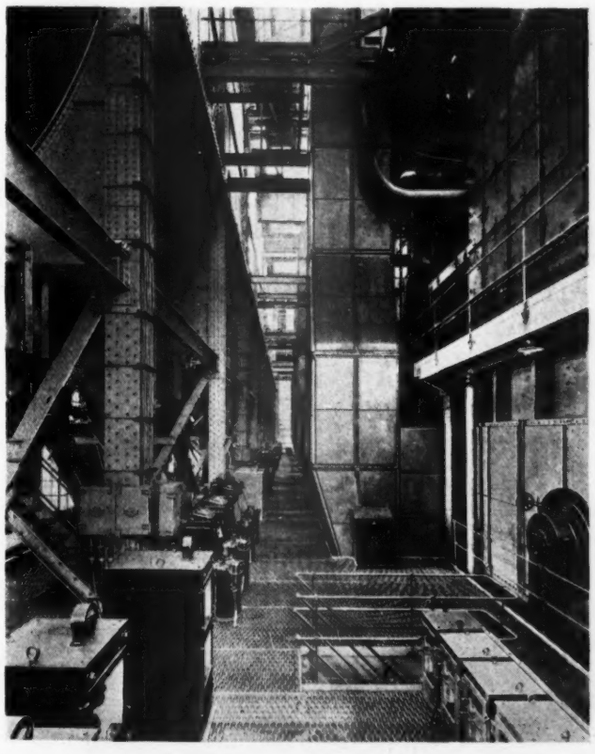
The flue gases leave the boiler at 275 deg. fahr. with 16 per cent CO_2 and are handled by a 40 in. double inlet Sirocco fan in duplicate. These fans discharge to a Davidson cyclonic gritcatcher, leading to a steel chimney, 8 ft. 6 in. in dia. and extending 56 ft. 6 in. above the roof level.

The ash is handled by Usco water sluice ash conveyors discharging to a settling sump of 360 tons capacity, water and ash.

The make-up water is the Birmingham Corporation water supply (Whitacre Reservoir) 15½ deg. total hardness, and is treated in a plant supplied by United Water Softeners, Ltd. consisting of a Lassen and Hjort lime and soda ash plant, closed sand filters with compressed air cleaning, and Base Exchange treatment using Permutit to give zero hardness water, the capacity being 12,000 gal. per hr. As regards the boiler feed pump circuit, this includes Hick Hargreaves deaerators and three independent centrifugal feed pumps of 50,000 gal. per hr. capacity, against a pressure of 480 lb. per sq. in. One of these is a Weir steam turbine driven unit, exhausting to feed water heaters, and the other two are Mather and Platt multi-stage electric driven units each driven by 440 hp. motors. The temperature of the water leaving the heaters is 295 deg. fahr.



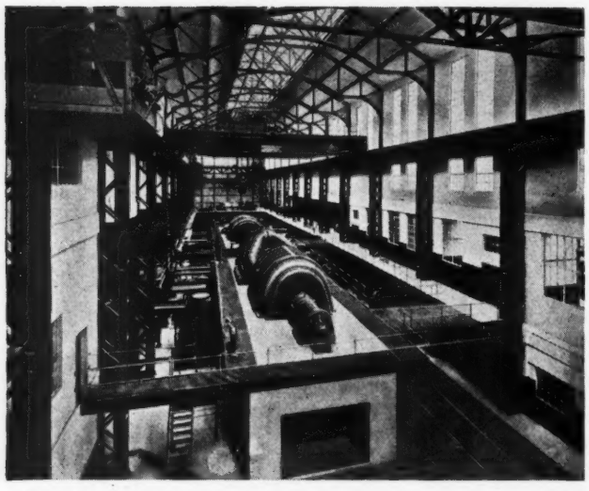
Another view of operating level showing control instruments and raw coal bins



View of boiler room at operating level. One of pulverized fuel burners is shown in the right foreground

In the generator building which is 309 ft. long, 62 ft. wide and 67 ft. high, are two 30,000 kw. Fraser and Chalmers turbines and G. E. alternators, 25 cycle running at 1,500 r.p.m. Steam is delivered to the turbines at 350 lb. pressure and 700 deg. fahr. Each turbine has one velocity wheel with two rows of blades, 17 impulse stages on the high pressure drum, 13 stages on two intermediate drums, and 6 wheels in the low pressure section, all of the fixed blades and most of the moving blades being stainless steel, the rest, like the shafts, being nickel steel. Two 1,875 kw. d.c. house sets are installed to meet the requirements of over 150 d.c. motors. Complete arrangements have been made for the installation of a third 30,000 kw. set.

The main condensers manufactured by Hick Hargreaves, Ltd., are of the surface type with 45,000



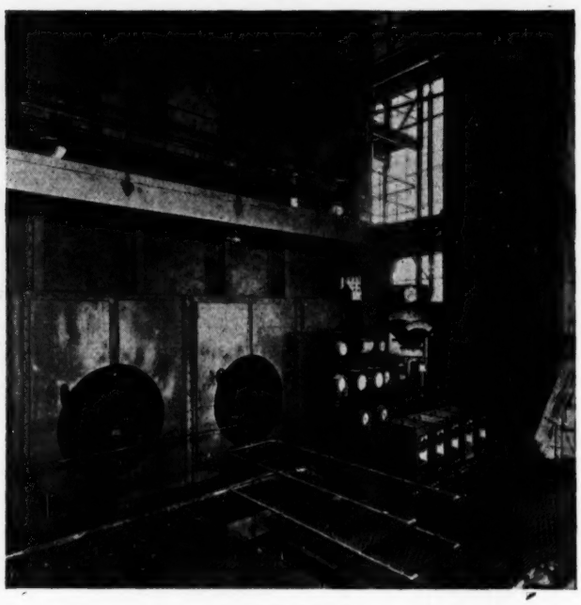
General view of turbine room showing the two 30,000 kw. generators now in operation

sq. ft. heating surface each and with a maximum duty of 26,500 gal. of water per minute at 75 deg. fahr., maintaining a vacuum of 28.1 in. mercury.

Perhaps the most striking feature of the Station is the two Cooling Towers, which are in fact the largest in the world. Each tower is 215 ft. high, and 175 ft. in dia. at the base. A vivid idea of what this size means can be gained from the fact that the Western Towers of Westminster Abbey could be placed completely inside one of them. The materials employed in their construction included 9,700 yd. of concrete, 480 tons of reinforcement, 3,400 tons of cement and 41,600 cu. ft. of permanent timber. Each tower can deal with 4,000,000 gal. of water in an hour., cooling it through 17 deg., from 93 deg. fahr. to 76 deg. fahr. The water is brought to the towers along concrete troughs at a height of 35 ft. above ground level, communicating with annular troughs on the outside which receive the water and conduct it through the tower shells to the distributing channels. These in turn allow the water to fall over the louvres to the pond below. The towers act as chimneys, and induce a draft which cools the water as it falls into the ponds. The ponds hold 1,736,000 gal. of water each, and both towers and ponds are so arranged that half of each can be closed while the other half is still working.

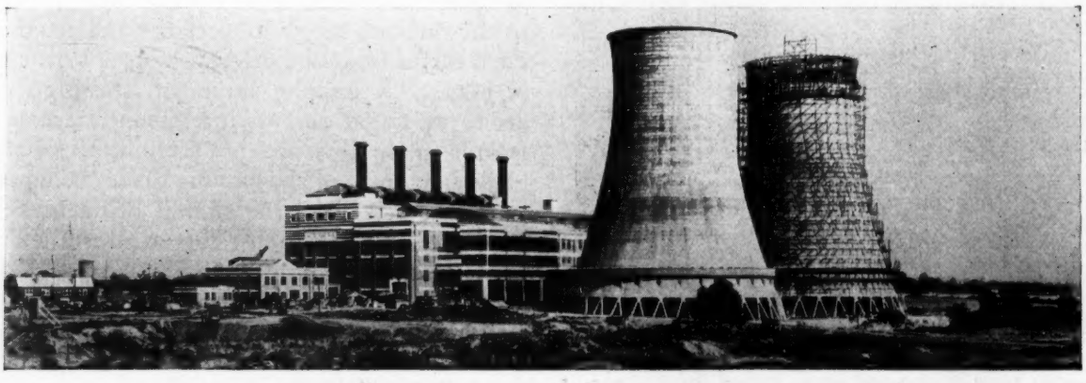
The towers are built upon base rings of reinforced concrete, which in turn rest upon mass concrete foundations extending to the solid ground below.

The materials required for this initial 60,000 kw. section included 2,000,000 bricks, 3,450 tons of steelwork, 8,000 cu. yd. of concrete and 53,000 sq. ft. of glazing. The total excavation was 165,000 cu. yd. Over 7,000 sq. yd. of road have been laid in addition to extensive railway sidings with accommodation for over 400 trucks.



Close-up of one of the boilers showing two pulverized fuel burners and meter panels

As regards the calculated performance of the station, the steam generation efficiency is 81.75 per cent with low grade coal of 8,000 B.t.u. per lb. and 20 per cent moisture, after deducting all auxiliary power, while the over-all thermal efficiency from the raw coal to the switchboard is expected to be 23.3 per cent on normal load.



The two enormous cooling towers shown in this view are said to be the largest in the world

- NEWS -

J. V. Santry Heads Combustion Engineering Corporation

J. V. Santry

Wilfred R. Wood and the Irving Trust Company, Receivers of Combustion Engineering Corporation, New York, have announced the appointment of Joseph V. Santry as head of that organization to succeed Col. H. D. Savage, who is assisting the Receivers.

Mr. Santry, who became identified with Combustion Engineering Corporation shortly after its organization in 1914, served successively as director and vice-president in charge of sales for five years and as president for four years, resigning about two years ago.

Predicts 'Super-Power' Plants In Natural Gas Industry

Developments in the natural gas industry during 1930 will see consolidations of operating companies, extension and inter-connection of pipe lines, looking to the creation of gas "super-power" systems, according to the following recent press report of a statement by John E. Kelly, vice-president of the natural gas subsidiaries of Inland Utilities, Inc., in West Virginia and Kentucky.

"The industry has made rapid progress in the last few years. While both manufactured and natural gas consumptions have risen since 1920, the latter has more than doubled, while the former has increased but 61 per cent. In the same period, revenues were in the same ratio, natural gas doubling and manufactured rising 65 per cent. More than $1,900,000,000 is now invested in the natural gas industry. Moreover, investment bankers and utility corporations are evidencing increasing willingness to participate in it as they see the great demand for this fuel throughout the country and realize that reserves can now be determined with greater accuracy than ever before.

"Although the industry has become one of the most important in the country, it still has its greatest development ahead of it. Already, certain companies have shown the advantages of linking production, piping and marketing units in super-power organizations, bringing to bear the same benefits of large-scale operations that have been so successful in the electric field. This tendency is only beginning and 1930 is expected to see its greatest intensification."

N. E. L. A. Prize Awards

The National Electric Light Association has announced the following prize awards for the best papers on subjects relating to the Electric Light and Power Industry.

"Doherty Prize, General: A gold medal donated by Mr. Henry L. Doherty, president of Henry L. Doherty and Company, for the best paper on any subject relating to the electric light and power industry.

"H. M. Byllesby, Accounting Prizes: Cash awards of two hundred and fifty ($250) dollars, one hundred and fifty ($150) dollars, and one hundred ($100) dollars, donated by H. M. Byllesby and Company, in memory of Colonel H. M. Byllesby, for the three best papers showing how to increase the usefulness of the accountant in the public utility industry.

"Martin J. Insull, Public Relations Prize: A cash award of two hundred and fifty ($250) dollars donated by Mr. Martin J. Insull, president of the Middle West Utilities Company, for the best paper dealing with public relations in the electric light and power industry.

"James H. McGraw, Engineering Prizes: Cash awards of two hundred and fifty ($250) dollars, one hundred and fifty ($150) dollars, and one hundred ($100) dollars, donated by Mr. James H. McGraw, chairman of the board, McGraw-Hill Publishing Company, for the three best papers on any engineering or technical subject relating to the electric light and power industry.

"James E. Davidson, Commercial Prizes: Cash awards of two hundred and fifty ($250) dollars, one hundred and fifty ($150) dollars, and one hundred ($100) dollars, donated by Mr. J. E. Davidson, president of the Nebraska Power Company, for the three best papers dealing with commercial or merchandising problems of the electric light and power industry."

Complete details concerning the awards may be secured by addressing the Secretary, National Electric Light Association, 420 Lexington Avenue, New York.

The National Association of Power Engineers will hold their 48th Annual Convention at the Cleveland Public Auditorium, Cleveland, Ohio, September 8th to 12th. As in previous years, a Power and Mechanical Exposition will be held in conjunction with the convention.

Move To Reorganize Federal Power Commission

IT is reported that legislation will shortly be introduced calling for a reorganization of the Federal Power Commission, as was requested by President Hoover in his message to Congress.

At present, the Power Commission is composed of the secretaries of Interior, War and Agriculture. Mr. Hoover favors a permanent organization, so constituted that the service of Cabinet officers on this commission will not be necessary.

Bituminous coal production during the week ended January 11th, according to the Bureau of Mines, was estimated at 11,166,000 net tons, as against 10,116,000 tons in the preceding week. The daily average production for the week ended January 11th was 1,861,000 tons as compared with 1,873,000 tons for the previous week and 1,945,000 tons for the corresponding week in 1929.

The total production of bituminous coal during the present coal year to January 11th amounted to 404,553,000 net tons. Figures for corresponding periods in other recent years are given below:

Net Tons	Net Tons
1928–29—388,956,000	1926–27—446,909,000
1927–28—367,113,000	1925–26—410,594,000

General Refractories Company, of Philadelphia has acquired the refractories properties of Evens & Howard Fire Brick Company of St. Louis. The purchase includes not only plants and business, but also important clay lands in Missouri and Georgia.

This now gives General Refractories a total of eighteen plants with a capacity of almost 1,200,000 bricks a day.

Evens & Howard Fire Brick Company plants will be operated as Evens & Howard division of General Refractories.

James Cleary has been appointed General Sales Manager of Combustion Engineering Corporation, New York. Mr. Cleary joined the organization in 1921 and has served successively as District Manager at Philadelphia and Detroit, Assistant General Sales Manager and Western Manager with offices at Chicago.

Mr. Cleary will assume his new duties at New York at once.

The Ironton Fire Brick Company, Ironton, Ohio, has announced the appointment of the Knoxville Sand & Lime Company, Knoxville, Tennessee, as local representatives for Ironton Fire Brick and refractory products.

Koppers to Acquire Coal Companies

IT is reported that one of the biggest consolidations in the history of the bituminous coal industry is soon to take place when the New England Coal and Coke Company, the New England Gas Company, the Mystic Steamship Line and Castner, Curran & Bullitt, Inc., will pass into the control of the Koppers Coal Company, of Pittsburgh, which is controlled by the Mellon interests.

The Koppers Coal Company, by obtaining control of the New England Coal and Coke Company and its subsidiaries, will become one of the largest operators of its kind in the world.

Samuel Insull, Jr., was elected vice-chairman of the Middle West Utilities Company at a recent meeting of the board of directors. Four new vice-presidents were elected: Oliver E. McCormick, vice-president in charge of the treasury department; E. A. Davis, vice-president in charge of auditing; W. S. Vivian, vice-president in charge of public relations, and Dempster MacMurphy, vice-president in charge of publicity. L. B. Breedlove was elected an additional assistant to the president.

Samuel Insull, Jr., has also been elected vice-chairman of the Public Service Company of Northern Illinois, Western United Corporation, and Western United Gas and Electric Company.

Charles E. Dunlap has been appointed president of the Berwind-White Coal Mining Company to succeed Edward J. Berwind, who will become chairman of the board of directors. H. A. Berwind and Thomas Fisher will retire as vice-presidents and Charles G. Berwind will become vice-president in charge of operations.

H. Kriegsheim, who has been President of the Permutit Company, of New York, for the past seven years, has been appointed Chairman of the Board of Directors, and W. Spencer Robertson, formerly Secretary of the American Locomotive Company, has been made President of the Company.

Mr. Kriegsheim will continue to take an active interest in the management of the company.

$2,000,000 Coke Oven Contract

The du Pont Ammonia Corporation, of Belle, W. Va., has awarded to the Wilputte Coke Oven Corporation, of New York, a contract for the construction of forty-eight coke ovens to cost $2,000,000. The project is scheduled for completion by September 1.

NEW CATALOGS AND BULLETINS

Any of the following literature will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Automatic Control

The Smoot system of boiler control is fully covered by a series of bulletins bound in a loose leaf folder. Separate bulletins describe the basic principles of control, and the application of automatic regulation to various fuels, furnace designs and load conditions. The control of boiler feed water pressure, automatic volume control of steam and air for Water Gas Sets and the Steam accumulator are among the subjects covered. 8½ x 11—Smoot Engineering Corporation, 136 Liberty Street, New York.

Boilers

C-E Boilers of the Heine Cross Drum Type are presented in Catalog No. 53-B. Both horizontally baffled and cross baffled types are included. The details of construction are illustrated and numerous application arrangements are shown and described. 32 pages, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Centrifugal Pumps

Lecourtenay Centrifugal Pumps are described in Bulletin 2111 and accompanying leaflets 2014 and H12. A wide range of designs and applications are covered including Boiler Feed Pumps, Fire Pumps, Circulating Pumps and Brine Pumps. 8 pages, 8½ x 11—Lecourtenay Company, Newark, N. J.

Cindertrap

Green's Cindertrap is described in two Bulletins Nos. 155 and 160. This apparatus was developed to provide a simple and reliable means for removing the coarser grades of cinders usually found in the flue gases of stoker fired and hand fired boilers. There are no moving parts, no water is used, and the draft loss is low. The Cindertrap is adapted for installation in a horizontal portion of the flue and can usually be installed without altering the adjacent equipment. An impressive list of installations is included. 4 pages, 8½ x 11—The Green Fuel Economizer Co., Beacon, N. Y.

CO_2 Recorder

The Apex CO_2 Recorder is described in Bulletin 118. This instrument is both indicating and recording and is offered as a simple, accurate and inexpensive device. The electrically operated APEX CO_2 Meter employs the orifice principle and an electric motor operated vacuum pump is used for drawing the gas sample through the instrument. No steam or water lines and no drain pipes are required. There are no moving parts in the instrument and no chemical solutions are employed. The electrical element consists solely of a motor suited to the electrical characteristics of the user. No batteries or delicate galvanometers are required. 6 pages, 8½ x 11—Uehling Instrument Company, 473 Getty Avenue, Paterson, N. J.

Draft Gage

New Catalog PGK-29 shows the Hays line of draft gages and combustion instruments including pointer gages of various types, pressure and temperature recorders, portable gages and manometers. The principles of operation, details of construction and methods of application are shown by numerous illustrations. 20 pages, 8½ x 11—The Hays Corporation, East 8th Street, Michigan City, Ind.

High Temperature Cement

Bulletin H-109A describes how "Hytempite" a high temperature cement may be used with crushed firebrick for furnace walls, baffles and repairs. It is pointed out that the old firebrick has less shrinkage and a higher fusion point than the original brick. Hence the old brick, when crushed and mixed with "Hytempite," forms a high grade refractory material for either repairs or monolithic construction. 24 pages, 3½ x 6¼—Quigley Furnace Specialties Co., 56 West 45th Street. New York.

Manhole Blowers

Coppus Manhole Blowers and Exhausters are presented in Bulletin 161-2. These blowers are driven by an electric motor and are used for the rapid cooling and ventilating of boilers, furnaces, stills, retorts and ovens. Three standard sizes have been developed one of which is mounted on a tripod and provided with a swivel joint so that the blower outlet may be directed either upwards or downwards. 4 pages, 8½ x 11—Coppus Engineering Corporation, Worcester, Mass.

Oil Burning Equipment

Enco Oil Burning Equipment, described in Bulletin OB-27 is available in both the steam atomization type and the mechanical atomization type. The principles and advantages of each system are discussed and numerous illustrations are included to show construction details. Brief mention is made of Enco Baffles and Enco Automatic Control (Balanced Draft). 8 pages, 8½ x 11—The Engineer Company, 17 Battery Place, New York.

Solenoid Operated Valves

"Asco" Solenoid Operated Magnet Valves are covered by a new looseleaf binder and included bulletins 800 to 827. These valves are adapted for use in connection with automatic regulation or remote control of gas, air, steam, oil or water. The various types of valves are well illustrated and tables of dimensions are included. 20 pages and cover, 8½ x 11—Automatic Switch Co., 154 Grant Street, New York.

Soot Blowers

Bayer Type "S" Steam Soot Blowers are described in detail in a well illustrated catalog. Three types of operating heads are offered—Balanced Valve-in-Head, Geared Head Encased and Direct Drive. 16 sketches are included to show various application arrangements and an inserted folder presents the advantages of Chromite air-cooled soot-blower elements. 24 pages and cover, 8½ x 11—The Bayer Company, St. Louis, Mo.

Steel Plate Construction

Modern methods of riveted and welded steel plate construction are described in a new illustrated catalog printed in three colors. Numerous illustrations show shop facilities and shop methods as well as examples of a wide range of completed work. A section at the end of the catalog is devoted to descriptions and specifications of Horizontal Tubular Boilers. 64 pages and cover, 8½ x 11—Struthers-Wells Co., Warren, Pa.

Underfeed Stoker

The Gifford Hydraulic Underfeed Stoker is illustrated and described in a new folder. This stoker is offered to provide the advantages of underfeed firing for small boiler units, up to 200 rated hp. The details of construction and application are well shown and specifications and capacities are given for the 8 sizes in which this stoker is built. 8 pages, 8½ x 11—Gifford Heat Control Systems, Inc., 1 Broadway, New York.

Valves

Bulletin 100 describes the Pittsburgh Valve Foundry and Construction Company's line of cast steel and iron gate valves, for steam, gas, oil and water. Specifications, tables of dimensions and list prices are given for a wide range of valves. 64 pages and cover, 6 x 9—Pittsburgh Valve, Foundry and Construction Co., 26th Street and Allegheny Valley R.R., Pittsburgh, Pa.

Welded Piping

A new booklet on Oxwelded piping is divided into two sections, Industrial Piping and Piping for Domestic and Industrial Heating. Many illustrations show a wide range of applications of welded piping to all manner of industrial uses and the text includes much valuable information on the subject. 20 pages, 8½ x 11—The Linde Air Products Co., 30 East 42nd Street, New York.

Wood Refuse Burning

Reprints are available of a technical article by H. R. Lambright, Plant Engineer, The Mengel Co. "300 Per Cent Rating Obtained with Wood Refuse and Powdered Coal in the Same Furnace." The boiler settings are of hollow air-cooled construction, with water-cooled side walls. The wood refuse is fired by Hofft stokers and a unit pulverizer provides for auxiliary firing with coal. 4 pages, 8½ x 11—M. A. Hofft Co., 814 West Washington Avenue, Indianapolis, Ind.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 MADISON AVE., NEW YORK

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured through In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Gas Analysis

By L. M. Dennis and M. L. Nichols

FOR the new edition of this standard treatise on Gas Analysis the entire book has been revised and reset and much new material added.

Since the publication of the earlier edition of this book in 1913, many important investigations in the field of Gas Analysis have appeared, and new lines of experimental investigation have been developed. Among the new topics that have been included in the present volume are methods of gas analysis that are based on thermal conductivity, new procedures for the determination of the specific gravity of gases, a description of the interferometer and its employment, and a detailed discussion of specific absorption and of the correction of barometric readings. Several methods that were given in the earlier edition, but which are no longer used or have been superseded by more satisfactory procedures, are now omitted.

In gas analysis the accuracy of the determination is probably dependent to a greater degree upon the manipulatory skill with which the work is performed than in any other branch of chemical analysis. It is for this reason that the manipulation of each of the more generally used types of apparatus is described at length by the authors.

The book, in its present revision, is one of the most authoritative, complete and up-to-date treatments of the subject available for text use with courses in Gas Analysis, or for general reference use.

It is bound in cloth covers, 5½ by 8, and contains 499 pages. The price is $4.00.

Heat Loss Analysis

By E. A. Uehling

IN THIS book it is demonstrated that the heating value of an amount of coal containing a pound of carbon is the same, within practical limits, for all coals of the same type. Thus, the heating value of a pound-carbon unit of bituminous coal is 17,900 B.t.u., semibituminous coal 17,600 B.t.u., and anthracite 16,300 B.t.u.

Taking advantage of this property of the natural fuels, simple formulas have been developed for calculating and analyzing the heat losses. The heating value of the pound-carbon fuel unit being constant, the engineer can determine the daily operating efficiencies of his boilers regardless of the analysis of his coal.

It is shown that the heat losses can be readily divided into two principal parts—controllable and uncontrollable. The controllable heat loss is shown to consist of two parts,—the loss due to excess air and the loss due to excess temperature. The firemen are primarily responsible for the former, and the boiler cleaners for the latter. A bonus system based on the heat actually saved by the respective operation is presented.

This book is intended for the operating personnel of the boiler house, to give them a clear understanding of the processes of combustion and heat absorption, and to serve the operating engineer in resolving the recorded data into the corresponding heat losses. It aims thus, to enable him to keep a close check on the proficiency of his men as well as the operating efficiency of his boilers.

The simplified formulas and methods presented are not claimed to be sufficiently accurate for scientific boiler testing—extreme accuracy having been sacrificed to gain simplicity and to further practical application.

This book is cloth bound, 6 x 8¼, and contains 240 pages. The price is $2.50.

The Creep of Steel at High Temperatures

By F. H. Norton

THIS book presents the results of an extensive investigation on the creep resistance of steels. The various types of steel tested were classified into three groups, i. e., austenitic steels, stainless steels and irons, and carbon and alloys steels. The tests were conducted at temperatures above 1,000 deg. fahr. and the results are presented in tabular and chart form. A number of interesting photomicrographs are included showing the structure of the metals at various stages of the tests.

The rapidly growing interest in the use of steam at high pressures and temperatures make the publication of this work particularly opportune.

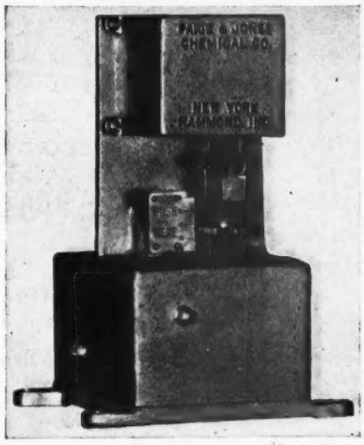
The book is cloth bound, 6 x 9¼, and contains approximately 100 pages. The price is $3.00.

• NEW EQUIPMENT •

Feed Water Treatment

THE Paige & Jones Chemical Company, Hammond, Indiana, manufacturers of water treating equipment, has developed a proportioning device for introducing the proper amount of chemical to render the water free of scale forming impurities.

The design of this proportioner is clearly shown in the illustration. Its foremost advantage lies in the fact that all raw water fed to the softener is measured by a standard water meter. On one of the metering shafts of this standard meter are located two simple fibre cams shaped somewhat like ratchet wheels with coarse teeth. Bearing on these cams are two springs provided with contact points which are used to open and close an electrical circuit.



Since the cams are identical, but staggered in relation to each other on the shaft, it will be seen that when the end of the upper contact-spring reaches the sharp depression in the cam, it will drop abruptly and make contact with the lower spring. This closes the circuit until the lower spring reaches the depression in its cam, when the circuit is abruptly broken.

The next step is to translate these impulses into mechanical motion that will regulate the chemical feed, and this is done in the most simple and positive manner by the electromagnetic unit shown at the left. Each time the circuit is completed the solenoid in the upper housing is energized. This causes its armature to be drawn up through the coil. An extension of this armature is connected to a rocker arm with a series of pawls which engage a ratchet wheel as brought out in the illustration. In this way the rotation of the ratchet wheel is made to maintain a fixed relation to the amount of raw water fed to the softener.

A screw or vernier is provided which regulates the stroke of the armature and therefore the movement of the ratchet wheel. This insures positive and accurate adjustment of the amount of chemicals for treating any given water.

This unit can be adapted to existing softeners, in which case it assures greater accuracy of feeding chemicals, the basic factor controlling the efficiency of a lime soda softener. An outstanding advantage of the unit is its small size.

Improved Gas Analyzers

THE Hays Corporation, Michigan City, Indiana, manufacturers of Combustion Efficiency Instruments, announces important changes in their line of Gas Analyzers (Orsats). This type of instrument, widely used in the determination of carbon dioxide, oxygen and carbon monoxide content of boiler flue gases, has been steadily improved during the past twenty-five years.

The present improvements provide a compact, rugged and ingenious Gas Analyzer with those features of design and construction demanded by Combustion Engineers, Service Engineers, Consulting Engineers, Operating Engineers and others who use such equipment.

Six standard ranges are available in a light weight metal carrying case weighing only 8 pounds complete and measuring 15 in. high x 7¾ in. wide x 4¼ in. deep. In addition there are three special ranges available in a slightly larger case.

Features of the New Hays Improved Gas Analyzer are:

1. Light weight and compact design.
2. Heavy moulded glass absorption pipettes which are attached to the moulded hard rubber chemical bottles with soft rubber gaskets and finger compression nuts.
3. Steel wool surface method of absorption of the gases being analyzed, making it possible to take a CO_2 reading in 30 seconds and a complete analysis for CO_2, O_2 and CO in from four to five minutes.
4. Monel metal needle valves and easily renewable nickel needle valve seats instead of pinch clamps and glass stop cocks.
5. Moulded hard rubber chemical bottles held in place by slidable flat spring

which can be raised after loosening the holding screw, permitting disassembly of the entire instrument for cleaning within two minutes' time. All parts are accessible. Only a pair of pliers and a screw driver needed to completely disassemble the instrument.

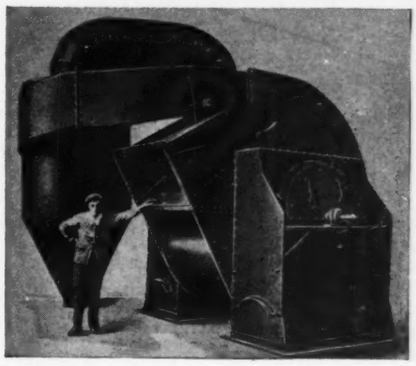
6. Owing to the method of supporting the few glass parts in the metal case there is little danger of breakage. All parts, however, are easily renewable in the field.

Dust Collecting Fan

THE Prat-Daniel Corporation, of New York, announces important improvements in the Type 4 Thermix Stack which combines in a single unit, an induced draft fan, a means of removing dust and cinders, and a stack for discharging the gas to the atmosphere.

For existing chimney and stack installations this can be furnished in the form of a Thermix Fan, without the Stack, placed similarly to an ordinary induced draft fan.

The principle of operation of the Type 4



Thermix Stack, or induced draft fan without stack is:

(a) The concentration of the dust by means of a prolonged involute of the fan.

(b) The continuous withdrawal of 5 to 15 per cent of this dust laden gas.

(c) The precipitation of the dust in a cyclone.

(d) The return of the cleaned gas from the cyclone to the suction side of the fan.

The fan scroll is made approximately twice that which would normally be the case with an ordinary induced draft fan. This concentrates the dust near the outside periphery of the scroll and, by means of an opening along this outside periphery, a portion of the gas is continuously withdrawn into the cyclone collector. The actual amount withdrawn may be regulated. If it is desired to remove the heavier particles over 100 mesh, this is accomplished by withdrawing a small quantity of gas to the cyclone at a slight increase in power for the operation of the apparatus. If the very fine dust from 250 to 300 mesh per inch is desired in addition, the stack may be constructed so as to take a larger section of the gas along the outside periphery of the scroll.

The withdrawn gas, after having been cleaned in the cyclone precipitator, is again passed through the fan. The cyclone thus has a second opportunity to collect any dust which may have escaped from it.

The inlet to the cyclone is under the plus pressure in the fan scroll and the outlet is under the negative pressure at the fan inlet. As the rating of the boiler increases, and the fan is operated at a higher speed to produce a higher draft, the dust remover accommodates itself automatically to the changed conditions, handling a greater amount of gas at a higher centrifugal speed with substantially the same percentage results in efficiency of dust removal.

The degree of dust removal can be definitely determined beforehand and the stack designed to meet these conditions, or the apparatus can be designed so that if operating conditions should change, the degree of dust removal can be regulated within certain limits.

PATENTS

Recently granted, and of Interest to our Readers.

Printed copies of Patents are furnished by the Patent Office at 10 cents each.
Address the Commissioner of Patents, Washington, D. C.

UNITED STATES PATENTS

Issued December 10, 1929

1,738,527. Furnace Arch. Bradley Dobie, Chicago, Ill., assignor to American Arch Company, a Corporation of Delaware. Filed Aug. 18, 1924.

1,738,544. Water-Screen Connection. John Van Brunt and George P. Jackson, Flushing, N. Y., assignors to Combustion Engineering Corporation, a Corporation of New York. Filed Aug. 1, 1923.

1,738,580. Furnace Arch. Raleigh J. Himmelright, New York, N. Y., assignor to American Arch Company, a Corporation of Delaware. Filed Aug. 15, 1924.

1,738,636. Furnace for Burning Finely Divided Fuel. Virginius Z. Caracristi, Bronxville, N. Y., assignor to Locomotive Pulverized Fuel Company, New York, N. Y., a Corporation of Delaware. Original application filed May 6, 1921. Divided and this application filed Dec. 1, 1925.

1,738,680. Furnace. Wade H. Wineman, Chicago, Ill., assignor to Sullivan Machinery Company, a Corporation of Massachusetts, Filed June 13, 1923.

1,738,707. Furnace-Wall Construction. Louis H. Hosbein, Winnetka, Ill., assignor to M. H. Detrick Company, Chicago, Ill., a Corporation of Illinois. Filed Oct. 1, 1924.

1,738,749. Traveling Grate Stoker. Richard Zinkernagel, New York, N. Y., assignor to International Combustion Engineering Corporation, New York, N. Y., a Corporation of Delaware. Filed Sept. 17, 1927.

1,738,774. Baffle or Wall. John H. Hinman, St. Louis, Mo., assignor to Heine Boiler Company, St. Louis, Mo., a Corporation of Missouri. Filed April 11, 1927.

1,738,817. Steam Boiler. Clarence F. Clemens and Albert H. Kemper, Dayton, Ohio. Filed Oct. 28, 1927.

1,738,848. Feed-Water Heater. Adolph Starr, Calumet City, Ill., assignor to The Superheater Company, New York, N. Y. Filed Feb. 3, 1928.

1,738,849. Superheater. Ernst Richard Stein and Karl Volland, Kassell, Germany, assignors to The Superheater Company, New York, N. Y. Filed Jan. 13, 1928 and in Germany Aug. 20, 1927.

1,738,901. Blast Furnace Tuyere. Ernest H. Holzworth, Buffalo, N. Y. Filed July 11, 1927.

1,739,035. Furnace for Pulverulent Fuel. Walter Kleinow, Hennigsdorf, near Berlin; Albert Morgenroth, Niederneunendorf; Friedrich Reinhardt, and Wilhelm Bruer, Velten, Germany, assignors to the Firm Allgemeine Elektricitats-Gesellschaft, Berlin, Germany. Filed Mar. 24, 1927 and in Germany May 1, 1925.

1,739,133. Combustion Apparatus. Robert A. Foresman, Moores, Pa., assignor to Westinghouse Electric & Manufacturing Company, a Corporation of Pennsylvania. Filed Jan. 26, 1925.

1,739,213. Pulverizing Apparatus. Ollison Craig, Worcester, Mass., assignor to Riley Stoker Corporation, Worcester, Mass., a Corporation of Massachusetts. Filed Oct. 19, 1926.

1,739,314. Centrifugal Cooling Device. John Karmazin, Detroit, Mich. Filed Sept. 17, 1925.

Issued December 17, 1929

1,739,497. Conveyor for High-Temperature Furnaces. George F. Beach, Philadelphia, Pa., assignor to F. J. Ryan and Company, Philadelphia, Pa., a Corporation of Delaware. Filed Mar. 12, 1926.

1,739,502. Steam Boiler. Carl T. Carlson, Erie, Pa., assignor to Erie City Iron Works, Erie, Pa., a Corporation of Pennsylvania. Filed June 15, 1925.

1,739,507. Air-Preheating Device. Otto De Lorenzi, Maplewood, N. J., assignor to International Combustion Engineering Corporation, New York, N. Y., a Corporation of Delaware. Filed Dec. 9, 1925.

1,739,594. Furnace Protection. George P. Jackson, Flushing, N. Y., assignor to Combustion Engineering Corporation, a Corporation of New York. Filed Feb. 13, 1924. Renewed May 9, 1929.

1,739,640. Apparatus for Preventing Incrustation in Steam Boilers. Joakime Kobseff, Bizerta, Tunisia. Original application filed Oct. 17, 1921. Divided and this application filed Aug. 21, 1923.

1,739,760. Steam Boiler. David S. Jacobus, Jersey City, N. J., assignor to The Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed May 21, 1924.

1,739,767. Heater. Thomas E. Murray, Brooklyn, N. Y., Joseph Bradley Murray, Thomas E. Murray, Jr., and John F. Murray executors of said Thomas E. Murray, deceased. Filed June 17, 1924.

1,739,836. Furnace. August Olaf Hansen, New York, N. Y., assignor to International Combustion Engineering Corporation, New York, N. Y., a Corporation of Delaware. Filed Aug. 2, 1927.

1,739,907. Furnace. George A. Kohout, Chicago, Ill. Filed Aug. 22, 1925.

1,739,969. Boiler Baffle. David S. Jacobus, Jersey City, N. J., assignor to the Babcock & Wilcox Company, Bayonne, N. J., a Corporation of New Jersey. Filed July 20, 1922.

1,740,145. Air Preheater. Harry H. Bates, Ridley Park, Pa., assignor to Westinghouse Electric & Manufacturing Company, a Corporation of Pennsylvania. Filed May 6, 1926.

1,740,239. Cylindrical Marine Boiler with Superheater. Simon Hoffman, Kassell-Wilhelmshohe, Germany, assignor to Schmidt'sche Heissdampf-Gesellschaft mit Beschrankter Haftung, Kassel-Wilhelmshohe, Germany, a Corporation of Germany. Filed July 31, 1928, and in Germany Sept. 8, 1927.

1,740,337. Steam Generator. John T. Cullen, Jr., Clinton, Iowa. Filed Aug. 4, 1928.

1,740,393. Sectional Furnace. Henry Cowles and James K. Norris, Utica, N. Y., assignors, by mesne assignments, to National Radiator Corporation, Dover, Del., a Corporation of Delaware. Filed Jan. 11, 1923. Renewed Jan. 18, 1929.

BRITISH PATENTS

Accepted December 2, 1929

322,194. Improvements in the Production of Briquetted Fuel. Imperial Chemical Industries Limited, of Imperial Chemical House, Millbank, London, S.W. 1., formerly of Broadway Buildings, Westminster, S.W. 1.

Accepted December 5, 1929

301,747. Improvements in or relating to Steam Generators. Maurice Eugene Chome, of 93, Rue General Leman, Bruges, Belgium.

303,510. Improvements in or relating to Furnaces Heated by Oil Burners. Rene Thery, of Indret, Loire-Inferieure, France.

306,154. Improvements in and relating to Pulverizing Mills. Hartstoff-Metall-Aktien-Gesellschaft (Hametag), of 39-42, Kaiser-Wilhelmstrasse, Berlin-Copenick, Germany.

308,579. Improvements in or relating to Processes for Briquetting Fuels. Chemisch-Technische Gesellschaft, M.B.H., of Kerkatorstrasse 76, Duisburg, Germany.

313,582. Improvements in or relating to Method of and Apparatus for Pulverizing and Treating Materials. Erie City Iron Works, of East Avenue, Erie, Pa., assignees of Walter Jacob Wohlenberg, of 54, Hubinger Street, New Haven, Conn.

317,078. Improvements in or relating to Dust Filters. Buhler Brothers, of Uzwil, Switzerland.

322,257. An Improved Liquid Fuel Burner. Percy Farrow, of 5, Waltham Terrace, Queenborough, Kent, and Canning Town Glass Works, Limited.

322,274. Improvements in Apparatus for Drying Broken Stone, Slag and other Material. Josiah Smart, Great Northern House, 345, Gray's Inn Road, London, W.C. 1.

322,276. Improvements in or relating to Apparatus for Discharging Coal and like Material from Wagon. James Henry Quick, 61A, Water Street, Port Talbot, Glam.

322,289. Improvements in and relating to Ash Ejectors. Frederick Niblock, of Plantation House, Keppel Harbour, Singapore, Straits Settlements.

322,303. Improvements in Regenerative Coke Ovens. Wilhelm Mueller, of 8a, Niederwallstrasse, Gleiwitz, Upper Silesia, Germany.

322,307. Improvements in and connected with Steam Generators. The Stirling Boiler Company, Limited, of 32-33, Farringdon Street, London, E.C. 4, and Henry Shilleto Horsman, of 140, Albert Palace Mansions, Battersea Park, London, S.W. 11.

322,327. Improved Drive for Jigger Conveyors. The Uskside Engineering Company Limited, of Uskside Iron Works, Newport, Monmouthshire, and John William Wood, of "Ridgedene," Alteryn Road, Newport, Monmouthshire.

322,341. An Improvement relating to the Utilization of Coke Ovens. N. V. Silica en Ovenbouw Mij, and Dr. Walther Hiby, both of 17, Raamweg, The Hague, Holland.

322,348. Improvements in and relating to Process and Apparatus for the Dry Distillation of Solid Carbonaceous Materials. Walter Edwin Trent, of 52, Broadway, New York City.

322,351. Apparatus and Process for Removing Distillation Product from the Lower Part of Coke Ovens or Retorts. Kurt Beuthner, of 124, Toniserstrasse, Krefeld, Germany, and Dr. Max Klonne and Dr. Moritz Klonne, sole partners of the firm Klonne, of 1, Kornebachstrasse, Dortmund, Germany.

322,362. Improvements relating to Water Tube Boilers. Hartley and Sugden Limited, of Atlas Works, Halifax, County of York, and Samuel Fox, Director of same company.